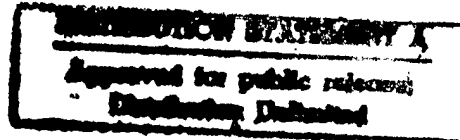


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6 August 1984



# USSR Report

ENGINEERING AND EQUIPMENT

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SYNTHESIS OF SYSTEM FOR STABILIZATION OF ENERGY DISTRIBUTION AND CONTROL OF REACTOR POWER ON BASIS OF LATERAL IONIZATION CHAMBERS

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 1, Jan 84 (manuscript received 16 Feb 83, final version 11 May 83) pp 1-15

YEMEL'YANOV, I.Ya., PODLAZOV, L.N., ALEKSAKOV, A.N., NILOLAYEV, Ye.V., PANIN, V.M. and ROGOVA, V.D.

[Abstract] Using lateral ionization chambers as local automatic regulators for stabilization of the radial-azimuthal energy distribution in a reactor and control of the reactor power, based on zonal asymmetry of the neutron balance operator and optimizable space structurization of the regulator array, is preferable to using sensors inside the reactor because of their better reliability and wider dynamic range. Such a regulator system has been synthesized in two stages. The first stage includes analysis of the system performance at constant nominal power level under conditions of unstable energy distribution and technological perturbations. The second stage includes analysis of the system performance during faults requiring externally controlled power reduction. Used in the first stage was a linear two-dimensional model of neutron stereokinetics with the linearized equation of diffusion accounting for one group of delayed neutrons and two first-order power feedbacks, fast feedback through fuel temperature and vapor content and slow feedback through graphite temperature and xenon poisoning. Selected as perturbation for response analysis was a step in time with uniform amplitude distribution over all harmonics, a model best fitting experimental data and sufficiently effective for practical design purposes. The optimum spacing of fuel rods was sought according to the criterion of minimum spatial dispersion of neutron flux deviations during reactivity perturbation. These calculations were programmed on a BESM-6 high-speed digital computer for comparative evaluation of theoretical and experimental data applicable to a 1000 MW water-graphite channel reactor. Subsequent calculations were done to determine the stabilizing characteristics of such a regulator system during steady-state operation as well as during faults, the respective basic performance parameters being the buildup time of residual distortions in the energy distribution pattern during lengthy steady-state operation of the reactor and the rate of power reduction to the level of normal cooling without change in the energy distribution pattern. Figures 4, references 9: 8 Russian, 1 Western.

[147-2415]

## METHODS OF CALCULATING STRESSED-STRAINED STATE OF FUEL MICROELEMENTS IN HTGR AND DESIGNING THEM

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 2, Feb 84 (manuscript received 22 Aug 83) pp 77-81

PONOMAREV-STEPNOY, N.N., SAZYKINA, T.A. and TIKHONOV, N.I.

[Abstract] Fuel microelements with pyrocarbon and carbide coatings are preferable to conventional fuel rods for high-temperature helium-cooled reactors, on account of both performance characteristics and safety. A microelement consists of a spherical fuel core 0.1-0.8 mm in diameter with a multilayer protective coating. The mechanical design of such a microelement is based on stress and strain calculations which, according to the theory of elasticity and its classical methods, involve solving the equations of balance, compatibility, and deformation. A set of programs has been developed at the Institute of Atomic Energy imeni I.V. Kurchatov in FORTRAN for calculating on a BESM-6 high-speed computer the stresses and strains depending on the flux density of fast neutrons and on the burnup level of heavy atoms. These programs include the LIN-2 program for fuel microelements with three deformable coating layers, with the KASATKA and BISON subroutines for continuing the calculations after breaking stresses in respectively one layer or two layers have been reached. Trial calculations were made for various microelement configurations covering the  $0-1.2 \cdot 10^{21}$  neutrons/cm<sup>2</sup> range of neutron flux density and the 0-10.0% range of burnup, a typical configuration being that of a 21% enriched UO<sub>2</sub> core 500  $\mu$ m in diameter surrounded successively by a 70  $\mu$ m pyrocarbon (1.0 g/cm<sup>3</sup>) buffer layer, a 60  $\mu$ m pyrocarbon (1.8 g/cm<sup>3</sup>) first reinforcement layer, a 40  $\mu$ m SiC (3.2 g/cm<sup>3</sup>) second reinforcement layer, and a 50  $\mu$ m pyrocarbon (1.8 g/cm<sup>3</sup>) third reinforcement layer. For design purposes the thickness dependence of maximum stress in the SiC layer has been calculated in three basic modes: 1) both pyrocarbon layers intact; 2) inner pyrocarbon layer broken and outer pyrocarbon layer intact; 3) both pyrocarbon layers broken. Figures 3, references 7: 2 Russian, 5 Western. [146-2415]

## STABILITY OF NATURAL CIRCULATION IN LOOP WITH BOILING COOLANT

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 2, Feb 84 (manuscript received 21 Apr 83) pp 74-77

BUDNIKOV, V.I. and SABAYEV, Ye.F.

[Abstract] Natural circulation of the coolant is analyzed for stability on the basis of a mathematical model which covers two situations of particular interest: 1) coolant at the loop entrance only slightly underheated so that

boiling starts at the beginning of the heated zone; 2) coolant at the loop entrance greatly underheated so that boiling starts only at the end of the heated zone. The mathematical model consists of three transient-state equations, namely one equation of pressure balance and two first-order differential equations for enthalpy, velocity, and specific volume, describing a quasi-homogeneous two-phase stream in the rising branch of a closed Field tube. Calculations are based on the theory of small deviations. Transfer functions are derived for the evaporation zone and the draft zone, first assuming that the pressure head in the former is negligible and then adding it as a correction. With the equation of pressure balance linearized, the sufficient condition for stability in each of the two cases is established from the roots of the corresponding characteristic equation. The authors thank A.L. Prigorovskiy for discussion. Figure 1, references 3 Russian. [146-2415]

UDC 621.039.564

# MULTICHANNEL CORRELATIONAL SYSTEM FOR MEASUREMENT OF COOLANT FLOW RATE IN WATER-GRAPHITE CHANNEL REACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 2, Feb 84 (manuscript received 3 Jun 83) pp 71-74

SELIVANOV, V.M., LYSIKOV, B.V., KARLOV, N.P., KUZNETSOV, B.A., MARTYNOV, A.D. and PROSTYAKOV, V.V. (USSR), PALLAGI, D., HORANI, S., HARGITAL, T. and TEZSER, S. (Hungary)

[Abstract] A multichannel system with a thermometric flow meter has been developed for inspection and analysis of the coolant in a water-graphite channel reactor. It operates according to the principle of correlation between random signals from thermoelectric transducers located in various fuel channels. These signals are amplified and filtered by a low-pass (0.5-8 Hz) device with an overall gain adjustable over the  $(0.5-6) \cdot 10^6$  range. This device consists of a preamplifier built with KT 3102/3107/325 low-noise high-frequency transistors, an amplifier proper built with four K284UD1A microcircuits, and an active filter built with four K553UD1A microcircuits. This device is followed by an analog-to-digital converter consisting of a comparator, a 16-channel analog module, a commutator switch, a programmable input-output stage, and a digital module. The digital module and the computer behind it are controlled by a Z-80 microprocessor. The cross-correlation function is calculated by the digital method according to a standard algorithm, with velocity and volume flow rate calculated as  $v = K_{1v} / (\tau_m \pm K_2)$  and  $Q = K_{1Q} / (\tau_m \pm K_2)$  respectively ( $K_{1v}$  - distance between transducers,  $\tau_m$  - transport time,  $K_2$  - correction for different time constants in different channels,  $K_{1Q}$  - calibration factor for flow meter). The quantization step can, depending on the coolant velocity, be varied over the 5-20 ms range. Experimental measurements indicate a slight increase of the error and a fast decrease of temperature fluctuations with increasing flow rate: the error of flow rate measurement remains below 5% over the 10-45 m<sup>3</sup>/h range with respective temperature fluctuations of 0.006-0.003°C. Figures 4, references 5: 1 Russian, 3 Hungarian, 1 Western. [146-2415]

## CONTROL OF ENERGY DISTRIBUTION IN VVER-1000 REACTOR AND SAFETY DURING OPERATION IN MANEUVERING MODE

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 2, Feb 84 (manuscript received 20 May 83) pp 67-71

FILIPCHUK, Ye.V., VOZNESENSKIY, V.A., DUNAYEV, V.G., LUK'YANETS, I.A., MITIN, V.I., POTAPENKO, P.T. and TIMOKHIN, Ye.S.

[Abstract] Operation of a VVER-1000 MW water-moderated water-cooled reactor in the load maneuvering mode, above base level, is considered and a strategy of power regulation is proposed which will ensure retention of the safe energy distribution in the reactor core during steady-state as well as transient periods. The algorithm of maneuvering is essentially that of finding the optimum sequence of control actions on power regulators and boron regulators which will transfer the dynamic system from its initial state  $S(0)$  to a zero final state  $S(N)$  within the minimum definite number of time intervals without departure from the required overall reactor power level, taking into account the maximum line power of fuel elements, the limiting rate of change of the fundamental axial neutron field component, and magnitude as well as speed of a control action, both limited by the finite reactivity which follows insertion of a regulator as well as by the finite rate of boric acid injection and dilution. The optimization problem for a quadratic criterion function,  $J = S^T(N)S(N)$ , reduces to a problem of quadratic programming, which can be solved by available numerical methods. Typical problems of safe maneuvering are power regulation at a rate of 1%/min with large reactivity margin and compensated boron regulators, power regulation at a rate of 5%/min, exceeding the capacity of boron regulators and requiring addition of an automatic power regulator, and unscheduled fast load dumping during emergency and fault clearance. Figures 4, references 6: 5 Russian, 1 Western. [146-2415]

UDC 536.25

## MATHEMATICAL MODEL OF HYDRODYNAMICS AND HEAT TRANSFER IN CORE OF HIGH-TEMPERATURE REACTOR WITH SPHERICAL FUEL ELEMENTS

Moscow TEPLOENERGETIKA in Russian No 12, Dec 83 pp 19-22

DENISOV, Ye.Ye., engineer, SUBBOTIN, V.I., corresponding member, USSR Academy of Sciences, and TSAREVSKIY-DYAKIN, S.N., candidate of technical sciences, All-Union Scientific Research Institute of Aviation Materials and Moscow Institute of Engineering Physics

[Abstract] A mathematical model of hydrodynamics and heat transfer in the core of a gas-cooled high-temperature or breeder reactor with spherical fuel elements has been developed which ensures stable results of calculation with

adequate engineering accuracy and highly economical use of computer time. Two- and three-dimensional flow of coolant through the core is calculated on the basis of a porous body as the physical model, also applicable to calculation of average flow in anisotropic media. In the hydrodynamic part of the model a channel-less core containing spherical fuel elements is regarded as an isotropic medium with high hydraulic drag so that only body forces and Archimedes forces appear in the equations of motion while viscous and inertia forces remain negligible. The corresponding three equations are: one which approximates the vector equation of force balance, the equation of Kirchhoff's first law applied to gas flow and approximating the condition of continuity, and the equation of Kirchhoff's second law for independent loops. In the thermal part of the model a core constitutes a porous medium with some equivalent thermal conductivity and heat transfer coefficient, local inhomogeneities comparable in size with the fuel elements being disregarded. The system of equations in this thermohydraulic model is formulated in matrix form for solution by the method of iterations with a grid covering the relevant core region, with a changeover from distributed ("smoothed") to lumped parameters. Results of calculations for the core of a 50 MW breeder reactor, including the flow rate and velocity field as well as the heat transfer and temperature field, agree rather closely with experimental data. Figures 2, references 15 Russian.  
[122-2415]

UDC 621.311.25:621.039

#### WATER CHEMISTRY IN AES WITH RBMK-1500 REACTOR

Moscow TEPLOENEGETIKA in Russian No 12, Dec 83 pp 4-7

MARGULOVA, T.Kh., doctor of technical sciences, ZORIN, V.M., candidate of technical sciences, TYAPKOV, V.F., engineer, and YURMANOV, V.A., engineer

[Abstract] Inasmuch as the reliability of reactors in single-loop AES depends largely on their water chemistry, particularly a low impurity content, a scheme has been developed which ensures adequate water purity in AES with RBMK-1000 MW water-graphite channel reactors. The main problem is treatment of feed water and condensate water, both contaminated with iron oxide and other steel corrosion products in addition to natural impurities. Water treatment in AES with RBMK-1500 MW reactors provides so far for purification of the turbine condensate only, by means of an ion-exchange filter. Meanwhile it will also be necessary to purify the feed water as well as water in the separator and in the drainage, for which electromagnetic filters have been found to be inadequate and mechanical "sand" filters (granules of styrene DVB copolymer) are very effective. Utilization of the condensate heat must be coordinated with condensate treatment, which precludes the otherwise highly economical pumping of the condensate directly back into the feed water system, and so must be the corrective batching of oxygen. Finally, structural materials for condensers, separators, steam exhaust pipes, deaerators, and pumps must be selected with maximum corrosion resistance

among the main requirements. A comparative evaluation of several steels has established that St 20 plain carbon steel is unsuitable even for heat exchangers, 08Kh18N10T stainless steel is adequate only during operation without oxygen enrichment, and 08Kh14MF nickel-free chromium steel is best. There still remains the problem of filter installations and maintenance, which includes periodic cleaning, most economically and with assurance of maximum biological protection. Figures 2, references 13 Russian. [122-2415]

UDC 621.311.25:621.039

# DECONTAMINATION OF EQUIPMENT IN AES WITH WATER-MODERATED WATER-COOLED POWER REACTORS

Moscow TEPLOENERGETIKA in Russian No 12, Dec 83 pp 11-13

BALABAN-IRMENIN, Yu.V., candidate of technical sciences, TEPLITSKIY, A.L., engineer, MATSKEVICH, G.V., engineer, NETESIN, V.B., engineer, TEPOV, P.V., engineer, and LUCHKIN, V.G., engineer

[Abstract] The main source of ionizing radiation in an AES is equipment of the first loop with a surface film of iron oxides containing radioactive nuclides. In order to protect the personnel against this radiation during reactor overhaul, it is necessary to decontaminate the equipment either individually or in aggregate. Most effective, especially in an AES with VVER water moderated water-cooled power reactors, is decontamination of the entire first loop as one aggregate. A new technique has been developed for this purpose at the All-Union Scientific Research Institute of Heat Engineering jointly with specialists from East Germany. It involves treating the film of iron oxides first with a solution of potassium permanganate and then with a complex etchant solution of ethylene-diamine-tetraacetic acid and citric acid. This technique was tried in an AES with a VVER-440 MW reactor, where the reactor shell made of plain carbon steel as well as three of the six steam generators were thus decontaminated, after the fuel rod assembly with protective and control equipment had been unloaded. An advantage of this technique is low waste, but it ceases to be expedient when the amount of metal requiring inspection and equipment requiring overhaul becomes large. Further studies were made to demonstrate the suitability of these solvents for decontamination of the reactor core with protective and control equipment as well, many components of the latter being made of bronze. The studies have yielded positive results so far, but actual experience in overhaul and subsequent operation is needed before the reliability of this technique can be certified. References 5: 3 Russian, 2 Western. [122-2415]

## RECONSTRUCTION OF VVR-K WATER-MODERATED WATER-COOLED RESEARCH REACTOR

Alma-Ata IZVESTIYA AKADEMII NAUK KAZAKHSKOY SSR: SERIYA FIZIKO-MATEMATICHESKAYA  
in Russian No 6, Jun 83 (manuscript received 17 Feb 83) pp 69-75

ARINKIN, F.M., BATYRBKOV, G.A., BEKMURZAYEVA, Z.B., GIZATULIN, Sh.Kh.,  
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[Abstract] The VVR-K water-moderated, water-cooled research reactor of the Institute of Nuclear Physics of the Kazakh SSR Academy of Sciences was rebuilt starting in 1969 to accommodate a large diameter channel for experiments (up to 140 mm) in the center of the core with a maximum thermal neutron flux density of about  $2.0 \cdot 10^{14} \text{ cm}^{-2} \cdot \text{sec}^{-1}$  at a reactor power of 10 MW. This paper details plans for the second phase of the reconstruction, which calls for increasing the core height from 600 to 1,200 mm, the installation of a lateral beryllium reflector (more efficient than the water counterpart) as well as boosting the reactor power to about 30 MW. This will greatly enhance in-pile experimentation capabilities. The two approaches to the reconstruction involve essentially either replacing the existing vessel or putting in the new one while simultaneously increasing the height by approximately 1,000 mm. Replacing the pressure vessel, although lengthening the retrofit time, will allow for increasing the size of the core separator, installing the side beryllium reflector with an effective thickness of 250 to 300 mm and increasing the central test channel to a diameter of 210 mm as well as modernizing other reactor systems. The former approach, though less labor intensive, makes it possible to rebuild the reactor in a relatively short time and construct a core 1,200 mm high with the beryllium reflector up to 110 mm thick and a central channel of up to 140 mm in diameter. Data are given from experimental studies of various cores 1,200 and 600 mm high with Be and water neutron reflectors, which were performed to substantiate the retrofit case involving no pressure vessel replacement. The various core lattice configurations are drawn and discussed, showing the pattern of fuel and control rod assemblies in the proposed cores. The neutron physics parameters of the cores are summarized in tabular form; the thermal neutron flux distribution over the height of the cores is graphed as well as the flux distribution over the core radius. Similar graphs are plotted for the central test channel. The best configuration is a 1,200 mm high core with a side beryllium reflector. The thermal loading will allow boosting the power to about 30 MW and producing a maximum thermal neutron flux in the center test channel, filled with water, of up to  $4.5 \cdot 10^{14} \text{ cm}^{-2} \cdot \text{sec}^{-1}$ . Figures 5, table 1; references 5 Russian.  
[115-8225]



UDC: 621.311.25:621.039

SELECTION OF DESIGN AND NUMBER OF STAGES FOR NUCLEAR HEAT AND ELECTRIC  
POWERPLANT DESALINATORS

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian  
No 9, Sep 83 (manuscript received 31 Dec 82) pp 53-58

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[Abstract] Some of the main results are presented from a technical and economic design study intended to select the optimal number of stages for an installation, as well as the dimensions of heat exchange surfaces in evaporators and heaters for both sea water and tap water. The study also determines the specific consumption of heat and adjusted cost of the production of distillate for various numbers of stages for combined installations under various conditions. Calculations were based on assumption of various costs of heat, specific cost of equipment per square meter of heating surface and costs of water at the plant. It was found that a combined multistage installation for desalination and heat supply has a number of advantages over installations in which tap water heating and desalination of sea water are separate processes. Combined installations can be planned for a maximum output equivalent to the full heating load in winter or in summer. In the former case productivity will decrease in summer, in the latter - in winter. Installations planned for maximum productivity in winter have greatest thermal and overall economy, but additional sources of fresh water are required in summer for such installations. The optimal number of stages is 7-10 in the winter or 10-12 if no loop-closing sources of water are present. Figures 3, references 4 Russian.  
[92-6508]

UDC: 62-83:621.039.524.44

ELECTROMAGNETIC DRIVE FOR NUCLEAR REACTOR CONTROL SYSTEM

Moscow ENERGO MASHINOSTROYENIYE in Russian No 10, Oct 83 pp 29-31

ZAV'YAPOVA, G.I., engineer and NIKOLAYEV, V.P., candidate of technical sciences

[Abstract] An electromagnetic drive for a nuclear reactor control system is described which incorporates a linear synchronous reactive electric motor operating in the step mode. A sealed housing isolates the high pressure zone of the primary loop of the nuclear reactor from the environment. The basic geometric relationships employed in the motor are presented. Figures 4, references 6: 5 Russian, 1 Western.  
[129-6900]

NON-NUCLEAR ENERGY

UDC: 621.316.925:621.313.12

SPECIFICS OF TNP-Sh CURRENT TRANSFORMERS AS PROTECTION AGAINST SHORTS TO GROUND IN BRANCHED BLOCK GENERATORS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 11, Nov 83 pp 65-67

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[Abstract] The operating conditions of current protection in case of internal or external full current short to ground using the TNP-Sh current transformer are the same as those obtained when the TNP-Sh is installed directly at the generator. Protection against shorts to ground can operate in case of a short to ground at the generator bus or in a generator winding. However, protection against double shorts to ground fails if the first short is on the generator stator, while the second short is on a bus or generator winding. The protection does operate with a double short to ground if one of the shorts is in the generator, while the other is in the external circuit. If a test alternating current with a frequency significantly less than the operating frequency of the system is superimposed on the generator 50 Hz voltage, protection can be provided against double shorts. Figures 2, references 6 Russian. [105-6508]

UDC 621.311.22.002.51,621.039

COMPARATIVE EVALUATION OF PICKUP PERFORMANCE OF GENERATING UNITS IN AES AND FOSSIL-FUEL ELECTRIC POWER PLANTS

Moscow TEPLOENERGETIKA in Russian No 12, Dec 83 pp 16-18

GOLOVACH, Ye.A., candidate of technical sciences

[Abstract] The pickup time for a generating unit in an AES or fossil-fuel electric plant determines its ability to participate in the power regulation system designed to avoid shutdown in the case of faults. Dynamic characteristics of 300 MW power units, namely their transient response during constant-pressure operation and during sliding-pressure operation under other conditions

as nearly equal as possible have been plotted on the basis of both calculations and measurements covering a period of 300 s after a 10% step increment of power. The experimental data represent averaged readings taken in three GRES with gas-oil fueled uniflow boilers (TGMP-314 boilers in Sredne-Uralsk and Lukoml power plants, PK-14 boilers in Konakovo power plant) and in one AES with VVER-440 MW water-moderated water-cooled power reactors (Novovoronezh power plant). Calculations on the basis of mathematical models were, in addition, made for an AES with a VVER-1000 MW reactor or an RBMK-1000 MW water-graphite channel reactor and a K-1000-60-1500 rpm turbine or a K-1000-60-3000 rpm turbine. The results roughly confirm previous experience and data, namely that in general AES generating units pick up faster than fossil-fuel units during operation under constant pressure and at least as fast during operation under sliding pressure. Figure 1, references 17 Russian. [122-2415]

UDC: 662.997.004.14

#### STUDY OF PROCESSES OF HEAT AND MASS TRANSFER IN PLANAR SOLAR COLLECTOR AT SUB-ZERO TEMPERATURES

Tashkent GELIOTEKHNICA in Russian No 5, Mar 83 (manuscript received 22 Dec 82) pp 58-63

UMAROV, G.Ya., TOVARNYKH, G.N. and UMAROV, S.G., Moscow Higher Technical School imeni N. E. Bauman, Ministry of Higher and Specialized Secondary Education, USSR

[Abstract] A study is presented of the process of freezing of water in a solar collector at night, considering the stress-strain state of panel walls and heat and mass transfer. Assuming that the water freezes at night, radiant flux from the sun is ignored in the calculations, but the thermal radiation of collector surfaces is considered. It is assumed that heat propagates through panel elements only in the transverse direction, perpendicular to the radiating surface. The water temperature is assumed constant, equal to the melting point of ice. Temperature is distributed linearly in the non-moving elements. Heat transfer coefficients from the moving medium to the nonmoving elements are assumed known. The thermo-physical properties of the medium are assumed constant. Field experiments were performed with strain gages cemented to the walls of solar panels, showing satisfactory agreement between theoretical and calculated values. Figures 2, references 5 Russian. [100-6508]

UDC: 662.997:537.22(088.8)

## TWO-LAYER COATING FOR THERMAL SOLAR COLLECTORS PRODUCED BY HYDROLYSIS

Tashkent GELIOTEKHNICA in Russian No 5, Mar 83 (manuscript received 1 Jun 82)  
pp 37-38

GUKHMAN, G. A., KOLTUN, M. M., MALIK, A. I. and UMAROVA, M. I. State Scientific Research and Power Engineering Institute imeni G. M. Krzhizhanovskiy

[Abstract] A two layer selective coating for aluminum alloy collectors has been developed with high absorptive capacity in the area of the solar spectrum and good operational stability. The coating consists of an  $\text{Al}_2\text{O}_3$  oxide film with black metallic nickel particles inserted into its pores and a film of  $\text{SnO}_2$  which is transparent to solar radiation. The authors of this article studied the possibility of producing a two layer selective coating of this type in a single technological process. Hydrolysis was used to apply both layers in a single process to duralumin plates at a temperature of about  $500^\circ\text{C}$ . The black oxide layer consisted of  $\text{Cu}_2\text{O}$ , the transparent layer was  $\text{SnO}_2$ . The process was performed using a special polarizer capable of producing films 50 to  $500 \text{ \AA}$  thick and briefly heat treating each film. The method of forming coatings by sequential application of thin films can significantly improve thermal and light stability by reducing internal stresses. Figure 1, references 3 Russian.

[100-6508]

UDC: 621.362:621.383.5

## SOLAR ELEMENTS WITH DISTRIBUTED PARAMETERS

Tashkent GELIOTEKHNICA in Russian No 5, Mar 83 (manuscript received 3 Jan 82)  
pp 3-6

ARIPOV, Kh. K. and RUMYANTSEV, V. D., Institute of Physics and Technology imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] This work is dedicated to theoretical construction and experimental verification of universal equations describing the effectiveness of photoelectric conversion and photocurrent over a broad range of light levels, extending into deep saturation of the solar elements. The measure of effectiveness is the ratio of electric power generated by a solar cell at the optimal load point to the maximum power which would be generated at the same light level with no internal ohmic losses. Solar cells with a p-n junction made of GaAs with an AlGaAs surface structure were used for experimental confirmation of the curves generated by the theoretical equations. Good agreement between theoretical and experimental data confirms the possibility of practical utilization of the equations derived to predict the behavior of solar cells of various configurations over a broad range of light levels. Figures 3, references 5 Russian.

[100-6508]

UDC: 621.472

# FUNCTIONAL STRUCTURE OF AUTOMATIC HELIOSTAT CONTROL SYSTEM FOR ELECTRIC POWERPLANT

Tashkent GELIOTEKHNICA in Russian No 5, Mar 83 (manuscript received 10 May 82)  
pp 32-36

DUBILOVICH, V. M., Belorussian Branch, Power Engineering Institute imeni  
G. M. Krzhizhanovskiy

[Abstract] The automatic heliostat control system described in this article can operate in several modes, both normal and emergency. Normal modes include tracking the visible movement of the sun, tracking the sun on cloudy days and transfer to the sunrise position for the next morning. Emergency modes include operation with equipment failure or under poor weather conditions. The system tracks the visible sun when possible, or follows where the sun should be according to the internal control rules recorded in memory. When the sun is not visible, the shape of the reflecting surface is altered so that should the sun come out from behind a cloud, the full force of its radiation will not be concentrated on the boiler, in order to avoid sudden changes in boiler temperature. The expected annual savings to be achieved by using these controllers is 300 to 500 rubles per controller, or 0.48-0.80 million rubles for a large solar electric powerplant. Figures 2, references 4 Russian.  
[100-6508]

UDC: 621.565.83:621.362

# MINIATURE THERMOELECTRIC CASCADE COOLERS

Tashkent GELIOTEKHNICA in Russian No 6, Jan 83 pp 55-58

NAYER, V. A., BELOZOROVA, L. A., SPIVAK, V. S. and KHIRICH, A. Ya.

[Abstract] The construction of an 8-cascade miniature cooler is described. Tests of the device indicate a minimum temperature achieved in the 8th cascade of  $t_0=135.2$  K. The current passing through the thermo-pile is 55 A, with power consumption of 200 W. Investigation of the miniature coolers indicate that it is now possible to develop cascade coolers at the 130-140 K temperature level consuming 100-150 W and providing cooling capacity of 20 mW. This is sufficient to support the efficient operation of a broad class of solid state devices. Figures 3, references 5 Russian.  
[107-6900]

DESIGN METHOD FOR FLAT-PLATE SOLAR COLLECTOR

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 52-55

KUZHARENKO, V. N., PODOL'SKIY, A. G. and FEDOSOVA, A. P.

[Abstract] A flat tube-type solar collector is examined in which the sheet thickness is significantly smaller than its length and width, permitting the temperature gradient through the sheet to be disregarded. A PL1 program was written to implement the algorithms proposed. The method can be used to calculate the thermal processes occurring in a collector with fixed as well as time-varying parameters of the environment and solar radiant flux. This allows the method to be used to design and optimize solar collector constructions. Figures 2, references 4 Russian.  
[107-6900]

EXPERIMENTAL TEST-BED INVESTIGATIONS OF SOLAR POWERPLANT HELIOSTAT CHARACTERISTICS: STATIONARY HELIOSTAT METHOD

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 38-41

TEPLYAKOV, D. I. and APARISI, R. R.

[Abstract] The stationary heliostat method is used to eliminate the testing problems which arise when the tracking method is used. A table is presented showing the variation in the noonday azimuth velocities of apparent movement of the solar disk across the sky for the 15th of each month for  $p-45^\circ$  north latitude. The photo detectors can be mounted on a special measurement screen, or a simple mast can be employed, either stationary and vertical (which is preferable for noon-day experiments), or tilting at an angle determined by the time at which the experiments are conducted. The method is equally applicable for diagnosing both flat and focusing power-type reflectors. Figures 1, references 7 Russian.  
[107-6900]

UDC: 662.997:001.57.8

INVESTIGATION OF HEAT LOSS OF SOLAR POWERPLANT RADIATION COLLECTORS OF DIFFERENT SHAPES

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 34-37

UMAROV, G. Ya., FATTAKHOV, A. A., UMAROV, A. G. and KHATAMOV, P.

[Abstract] This study investigates heat losses of open solar powerplant collectors and seeks ways to improve their thermal efficiency. It is proposed that collector efficiency be improved by combining the properties of a hollow collector and a circular selector, i.e., comparing collectors with smooth surfaces and circular irradiation made of a collection of separate cells. The convective losses for both types of reflectors are similar; however, the reflection losses of the cellular reflector are considerably lower than those of an open type collector. As a result, the cellular collector is 13-15% more efficient than the open type. The surface of a cellular collector of the same size is 4-6 times more developed, making it promising for solar powerplants. Figures 2, references 5 Russian.  
[107-6900]

UDC: 662.997:537.22

CALCULATION OF PROFILES OF SOLAR FRESNEL LENSES

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 31-34

TVER'YANOVICH, E. V.

[Abstract] A method is presented for calculating the profile of Fresnel lenses to be used as solar concentrators. The lens profile is calculated by finding the angle corresponding to the optical sections  $r_{\max}$  for a given focal length  $f$ , coefficient of refraction of lens material  $n$ , support layer thickness  $t_n$  and calculated surface  $t_p$ . It is demonstrated that lens profile calculation must be carried out as an optimization process with allowance for light losses in the lens: Fresnel reflection at the entrance and exit, and the flux value on the working profile with allowance for the desired energy distribution of the focal plane. The choice of the actual profile is determined by technological considerations, depending upon the lens material and forming method employed, as well as constructive and operating considerations. Figures 2, references 4 Russian.  
[107-6900]

UDC: 662.997:537.22

MOUNTING AND TRUING OF REFLECTING SURFACES IN LARGE SOLAR POWER INSTALLATIONS

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 26-31

AZIMOV, S. A., AKBAROV, R. Yu., BATURIN, V. V., KALANDAROV, B., PIRMATOV, I. I. and URYUPIN, S. A.

[Abstract] A group of studies aimed at solving the problems arising in the development and operation of major solar power installations is described. Special benches are developed for use in working out the mounting and alignment of concentrators in large solar furnaces and for investigating concentrating capability and other characteristics of concentrator elements. The devices described include a profilometer, as well as an optical device for testing facet shapes and a bench for truing facets in blocks of 25. Significant savings are achieved through the use of these aids. Figures 3, references 5 Russian.

[107-6900]

UDC: 661.383:621.472

STRUCTURE AND PROPERTIES OF THIN-FILM HETEROSYSTEMS WITH LAYER OF CADMIUM TELLURIDE

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 7-10

BOYKO, B. T., KOPACH, V. R., KOPACH, G. I., OPANASYUK, A. S., YEDYKIN, V. Ya. and SHPAKOVSKAYA, L. P.

[Abstract] This study presents a number of findings, directly related to the problem of developing ways of increasing the resistance of photovoltaic cells to degradation and of increasing converter efficiency, obtained from structural and electrophysical investigations entailing the growing and aging of base layers of CdTe for various converters. Films more than 0.2  $\mu\text{m}$  thick were deposited on conducting and nonconducting orienting and nonorienting metal, semiconducting and dielectric surfaces. The structure and substructure of the CdTe films, as well as of the materials contacting the CdTe were studied by X-ray and electron diffraction. Morphological studies were conducted with the help of raster and optical microscopy; electrically active point defects and the characteristics of charge transfer in CdTe were studied by the current-voltage characteristic method. References 13: 8 Russian, 5 Western.

[107-6900]



UDC: 621.362:621.383.5(088.8)

OPTIMIZATION OF TYPE OF HIGH VOLTAGE PHOTOVOLTAIC CELLS TO OPERATE WITH  
SOLAR RADIATION CONCENTRATORS

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 14-18

YEPIFANOV, M. S. and UNISHKOV, V. A.

[Abstract] Optimum dimensions are calculated for three shapes of high voltage photovoltaic cells and several radiation intensity distribution functions at the "focal point" of the concentrator (for two distributions measured experimentally for a Fresnel lens). The findings can be used to optimize the size and shape of high voltage photovoltaic cells and to develop power modules employing concentrators based on Fresnel and other types of lenses in order to develop high efficiency terrestrial and space powerplants. Figures 5, references 1 Russian.

[107-6900]

UDC: 621.383:621.472

INVESTIGATION OF DEEP CENTERS IN SILICON PHOTOVOLTAIC CELLS BY THERMOSTIMULATED  
CAPACITANCE AND INDUCTANCE METHODS

Tashkent GELIOTEKHNIKA in Russian No 6, Jan 83 pp 10-14

BUZANOV, L. K., VERSHININ, V. S., GLIBERMAN, A. Ya. and KOVALEV, I. I.

[Abstract] The activation energy of deep centers can be determined sufficiently accurately by the formula  $C_f = A \exp(-E_T/2kT)$ , which disregards the temperature dependence of the cross section of the deep levels. Two types of photovoltaic cells are studied which were made of p-type silicon with resistivity of approximately 200 and 1000  $\Omega \cdot \text{cm}$ . The deep p-n junction is created by two-stage diffusion of phosphorus, and reverse aluminum and boron doping is used to create the  $p^+$  layer. When aluminum is used for alloying to create the  $pp^+$  layer, deep centers are generated with activation energy of 0.36-0.4 eV in p-type silicon with resistivity resistance of 200-1000  $\Omega \cdot \text{cm}$ . References 9: 7 Russian, 2 Western.

[107-6900]

UDC: 621.181.62-501.22

EXPERIMENTAL DETERMINATION AND ANALYSIS OF DYNAMIC PROPERTIES OF 300 MW  
GENERATING UNITS

Moscow ENERGO MASHINOSTROYENIYE in Russian No 1, Jan 84 pp 9-11

KULAKOV, G. T., candidate of technical sciences and LITVINETS, V. I.,  
engineer

[Abstract] This study examines a 300 MW gas/oil unit employing single- and dual-furnace boilers with capacities of 1050 and 950 tons per hour and a K-300-240 LMZ turbine. Multifactor analysis was performed in order to obtain more complete data on the dynamics of the boiler-turbine system for use in synthesizing an automatic power regulation system and in designing basic system components. Comparison of the dynamics of the single- and double-furnace units revealed only minor differences in their properties. Figures 3, references 5 Russian.

[130-6900]

UDC: 621.224.35

WATER ALIGNMENT IN VERTICAL HYDROELECTRIC UNITS

Moscow GIDROTEKHNIЧЕСКОYE STROITEL'STVO in Russian No 1, Jan 84 pp 29-34

SHCHEGOLEV, G. S., professor and ZABELKIN, V. M., engineer

[Abstract] This study reviews methods for reducing hydraulic unit vibration by controlling shaft wobble in the area of the turbine and generator bearings. Assigning tolerances for turbine shaft journal wobble by combining a portion of the errors by a minimax method results in elevated values. Calculation of wobble by adding together probabilistically all of the manufacturing tolerances specified in the drawings indicates that the dispersion field of the shaft offset significantly exceeds the normative values which have been established through experience. The main component of shaft wobble is due to the contacting planes of the parts of the thrust bearing being out of parallel with respect to the base surface to which the shaft flange is connected. Eliminating simultaneous truing of the holes in the flange connectors of the turbine and generator shaft makes it possible to orient the rotor frame with respect to the shaft in the best possible way. Figures 4, references 14 Russian.

[117-6900]

UDC 621.865.8

STRUCTURAL DESIGN AND KINEMATIC CONFIGURATIONS OF TWO-ARMED ROBOTS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 12, Dec 83 pp 5-9

PAVLENKO, I.I., candidate of technical sciences

[Abstract] It is best to determine the structural design and kinematic variants of two-armed robots without considering the degrees of mobility of the kinematics of the base or the degrees of mobility common to the kinematically coupled arms or the kinematics of the wrists, since these motions comprise separate kinematic groups to be analyzed independently. The structural configurations of two-armed robots are those which are distinguished by the distribution of the degrees of mobility between the arms, the composition of the kinematic pairs, the kinds of motions they can execute and the relative positioning with respect to each hand. This paper defines five degrees of mobility for the robot arms with nine different variants of the distribution of degrees of mobility between the arms and then analyzes the possible configurations of the kinematic pairs. The options are summarized in tabular form and a set of schematic drawings. The proposed approach makes it possible to select the most standard and acceptable kinematic variants for two-armed robots from a set of possibilities and can also be extended to the analysis of kinematic configurations for multi-armed robots. The purely theoretical treatment adduces no specific calculations or examples of designs or hardware. Table 1, figures 2, references 4 Russian.  
[119-8225]

UDC 621.96.621.78-97:669.018

EXPERIENCE WITH INTRODUCTION OF FINISH PERFORATION OF PRECISION PARTS FOR OPTICAL INSTRUMENTS

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 37-40

VISHNEVSKIY, N.S., NEUGOMONOV, Yu.N. and MAZITOV, V.V.

[Abstract] Finish perforation of precision parts has been introduced in an enterprise which produces binoculars and other optical instruments with

general-purpose and special-purpose manufacturing equipment. The perforating machine is a 400 kN model K234 cam press with GKP-F-50/80 Feintool (Swiss) automation. The press can be set up for perforating blanks of carbon steels with 0.2-0.8% C (grades 10kp, U8A, 20, 40, 45, 50), brass (grade L63T), or aluminum alloy (grade D1AT) 8-50 mm long, 4-50 mm wide, 46 mm in diameter, and 0.8-5.0 mm thick. The product quality was evaluated on the basis of standard mechanical tests (hardness, yield strength, ultimate strength, ductility) and microstructural analysis. The results have revealed effects of heating and heat treatment during punching, in terms of phase transformation and redistribution. Recommendations were made on this basis concerning punch and die design as well as method of operation for optimum condition of cut surface and minimum possible corner radius. For production volumes below 100,000 pieces, updating the general-purpose press is recommended, although it will produce only 6,000-7,000 pieces in one work shift, which is economically preferable to installing a much more costly special-purpose triple-action press. Figures 5, tables 3, references 2 Russian.  
[118-2415]

UDC 621.7.077:621.983.001

#### CALCULATING RELIABILITY AND PRODUCTIVITY OF COLD STAMPING ROBOT COMPLEX AS QUEUING SYSTEM

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 36-37

STEPANSKIY, L.G. and KRYUCHKOV, M.A.

[Abstract] A robotic complex for cold stamping is considered which includes either two industrial robots or one industrial robot with two hands, one for feeding parts to the press and one for dumping parts from the press. Its reliability and productivity are calculated by treating it as a queuing system. The probabilities of correct operation are evaluated on the basis of time parameters characterizing the cold stamping process, likely losses of time, and failure statistics. The results are extended to a complex consisting of  $k$  presses and  $2k$  industrial robots or  $k$  two-hand industrial robots, also  $k-1$  conveyers transporting parts from one press to the next. Such a system is treated as a  $(4k-1)$ -phase queuing system with failures and one channel or as a  $3k$ -phase queuing system when conveyers are excluded. General formulas are applied to a complex with a Tsiklon-3B two-hand industrial robot for a press which delivers a mean number of  $24 \cdot 10^3$  punches between failures with 700 piston strokes per hour. For the same example, the authors calculate the increase of overall productivity that would result from increasing the productivity of the input conveyer by 30% so that the blank feed time is reduced to 0.00154 h. The productivity of the robot complex is found to increase by 8% from its original 211 pieces/h. Reference 1 Russian.  
[118-2415]

## METHOD OF SELECTING ROBOTIZED SYSTEM DESIGN FOR PRESSING PROCESS

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 34-36

ARKHIPENKO, N.A. and KRAVCHENKO, N.F.

[Abstract] The design of any robotized system depends on the type of industrial robot and on the functions it is to perform as well as on the composition and the arrangement of the manufacturing tools. The optimum design for any technological process is based on comparative analysis and evaluation of available standard and special-purpose designs. The selection procedure for a pressing process is demonstrated considering seven different robotic complex designs and five different robot line plans to choose from. Their performance characteristics are quantified in terms of two economic indicators: annual cost saving and length of investment recovery period. The variables in the equations are productivity with industrial robot and productivity with conventional existing means. Their ratio must be larger than unity for further consideration of a given robotic structure. They are calculated from data on the technological process, including length of daily work shift, time required to produce one part, length of one press operation cycle, intercycle lost time (part insertion and removal), extracycle lost time (setup and later adjustments, repairs and overhaul), mean time between failures, and also length of each robot operation. The annual cost saving is calculated for each eligible robot design and the selection is made accordingly. Numerical calculations have been made by this method for the process of bending 20-50 mm long, 10-120 mm wide, 0.5-2 mm thick braces weighing not more than 0.2 kg in a K-117A press with an industrial robot. An industrial robot with low load capacity and one with a higher load capacity were considered. Figures 3, table 1, references 3 Russian.

[118-2415]

## EXPERIENCE IN CONSTRUCTION OF SHEET STAMPING ROBOTIC COMPLEXES

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 31-33

KIRASIROV, V.M., KUZNETSOV, N.N., POCHTAR', Yu.S. and TRAVKIN, N.V.

[Abstract] The general concept and organization of a sheet stamping robotic complex are described, with one industrial robot for one press and several special-purpose machine tools serving as typical example. The layout of production machinery with a model PR-10S industrial robot for producing cowls of various sizes and intricate shapes from blank disks is shown, from the beginning to the last finishing operation. This machinery includes a model P6328 hydraulic press, a model SZK-2VM facing tool, a model PD-1 piercing tool, and a stapler. The automatic manipulator has specially constructed feeder and gripper mechanisms. It operates with the machine tools

sequentially, according to requirements of the manufacturing process, through feedback control which also includes safety measures with use of verification signals and appropriate interlocking. This complex has been installed in the Stupino Metallurgical Combine, where it replaces four workers in stamping and mechanical processing operations and has made it possible to replace piecewise processing of blanks with a conveyor-belt line. Figures 5, reference 1 Russian.

[118-2415]

UDC 621.73.047.62-529

#### AUTOMATIC MANIPULATORS FOR FORGING ROLLERS

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 29-31

GLADKOV, F.A., RYABOV, A.M., SAZONENKO, V.A., SKLYAROVA, G.I. and SOKOLOV, V.N.

[Abstract] Two automatic manipulators MKV-50 and MKV-16 for hot rolling mills have been developed at the Taganrog Design Engineering and Technological Institute of Forging and Pressing Robotics, as components of automatic systems developed at the Voronezh Experimental Scientific Research Institute of Forging and Pressing Equipment Manufacture imeni M.I. Kalinin. These program controlled automatic manipulators, with respective load capacities of 50 kg and 16 kg, feed ingots from hoppers to multipass rolls and dump the product into bins. The servo-mechanism of each consists of a hand mounted on bearings in a case-carriage, the hand moving along the carriage and the latter moving parallel to the rollers. Each hand is coupled to a planetary gear mechanism through a power pack, a strap, a driving lever, and a connecting rod, also to a cylinder about whose axis it can rotate. Each automatic manipulator features a centralized fluid supply system for all its servo cylinders and a centralized lubrication system for all its friction couples. Its extensive program control is based on a standard UTsM663 memory storing the entire control algorithm, with provisions for manual control before start. An experimental MKV50 prototype was tested in an AKSV1237 robotic complex. One such automatic manipulator in a rolling mill should reduce the production cost by 42,000 rubles annually. Figures 2, table 1.

[118-2415]

UDC 621.73-52.62-506

#### UPDATING MODEL RPD-1.25 INDUSTRIAL ROBOT

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 27-29

SACHKOV, L.B.

[Abstract] The model RPD1.25 industrial robot has been developed at the Taganrog Design Engineering and Technological Institute of Forging and

Pressing Robotics, and is being series produced at the Salsk plant under supervision of the Planning and Inspection Department. This latest model incorporates new features in individual components as well as in the overall layout of the manipulator. The hands can now rotate clockwise and counter-clockwise about their vertical axes as well as up and down, each tong can move forward and backward along the hand axis, and the tong of the lower hand can also rotate about the hand axis. The hands are mounted so that they can remain in almost any position, at any angle, relative to the manipulator body. The rotating mechanism consists of a rotary piston engine with pinion. The lifting mechanism consists of a pneumohydraulic cylinder with bushing, regulating screws, and hydraulic cushions. The manipulator is mounted on the floor through four adjustable bolts so that its height above the floor can be varied by as much as 80 mm. Its mechanisms are enclosed for protection against dust, dirt, and foreign objects. The industrial robot is controlled by standard UTsM-663 hardware, it operates two presses on the model L16 assembly line replacing the old model RTU2.KD2124Ye robot complex. Figures 3, tables 2, references 5 Russian.  
[118-2415]

UDC 621.73:621.7.007.52.001

INDUSTRIAL ROBOTS AND AUTOMATIC MANIPULATORS FOR FORGING AND PRESSING OPERATIONS  
AT SECOND INTERNATIONAL EXHIBITION

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 25-27

DEZHUROV, R.K. and KOLOSKOV, N.V.

[Abstract] The Second International Exhibition in Leningrad displayed industrial robots produced by 32 manufacturers in 12 countries, more than 120 models for casting, forging and pressing, metal treatment, semifinishing, transport, assembly, painting, and other operations. The exhibits included hydraulic, pneumatic, and electric drive accessories for all these industrial robots. Outstanding among the automatic manipulators were the Andromat from France (CSEE) for drop forging, horizontal forging and pressing, putting blanks into furnace and taking blanks out of furnace, and four automatic manipulators from Austria (Reuthner GmbH): the SM for forging wheels, the SMES for forging rails, the ZM for transporting, and the hydraulic SMA for forging rods and barrels as well as for rough forging. Other interesting exhibits were the MARK II/III/IV/V automated centers from the United States (Aida Corp.) for coining coiled sheet, coining flat strip, multiposition coining of individual blank pieces, and cold stamping respectively. These centers operate with a "pacer" assembly line. Figure 1, tables 6.  
[118-2415]

## EVALUATION OF SOCIOECONOMIC EFFECT OF INTRODUCING INDUSTRIAL ROBOTS INTO STAMPING PRODUCTION

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 23-24

SHUSHKO, D.A.

[Abstract] Introduction of industrial robots into forging and pressing processes requires modification of available robots such as the Tsiklon-3B and Ritm-0.1/0.5 for higher productivity and faster operation. It also requires means of control, inspection, and performance evaluation. The socio-economic effect of their introduction is threefold: increase of work area to accommodate the larger capacity, decrease of labor content in the production cycle, change in payroll system and wage scale. These factors have been analyzed for hot and cold stamping, along with overall effects on investment and production costs, using criteria which facilitate breakdown into components and comparison not only with effects of conventional mechanization but also with effects of robotization in other countries (Japan). Operation of industrial robots with programmed digital control is considered. Calculations indicate that introduction of industrial robots into these processes has indeed significantly increased production output and labor productivity while reducing the production cost. Table 1, references 8: 7 Russian, 1 Western. [118-2415]

## PIECEWISE FEED OF FLAT BLANKS TO TONG OF INDUSTRIAL ROBOT

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 22-23

LETSIK, V.I.

[Abstract] The feed of flat blanks from top of a stack to the tong of an industrial robot is analyzed from the standpoint of kinematics and attendant force balance. An essential part of the problem is automatic maintenance of the given stack height without avoidable energy loss, which can be achieved with a hydrostatic mechanism operating on the basis of Archimedes' law. Such a mechanism consists essentially of a float in a water or oil tank coupled to a lever through a vertical stem carrying the stack. All forces acting in this system have been evaluated from physical and geometrical parameters of float and stack. Design formulas have been derived and float dimensions have been calculated on this basis. A prototype of the mechanism was built and tested. Tests were done on 1 mm thick blank disks of seven different materials: AM5 wrought aluminum alloy, micarta, brass, mica, steel, acrylic glass, and Textolite. Figure 1, table 1, reference 1 Russian. [118-2415]



## EXPERIENCE IN INTRODUCTION OF RITM-5 INDUSTRIAL ROBOT AND CALCULATION OF ITS COST EFFECTIVENESS

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 20-22

VASILEVICH, A.I., MAGAZINER, V.A., PAVLOV, A.M. and SHUSHKO, D.A.

[Abstract] A pressing plant has been robotized in two stages. Introduction of the Tsiklon-3B industrial robot for operating two KV-235 presses in the first stage was found to be uneconomic and its digital control system PUR-Ts to be insufficiently reliable. The technological complex was redesigned around the Ritm-05 industrial robot instead. This did not require replacing conventional means of setup automation, but necessitated raising the overall level of mechanization and automation. The four main problems solved here were automating the feed of blanks of various shapes, improving the design of tongs to ensure their ability to correctly identify and accurately position parts, automating the inspection of part seating in key accessory fixtures, and improving the design of gear and trimmer mechanisms to ensure high speed and high reliability. The cost effectiveness of such a robot complex then depends on subsequent organization of the manufacturing process. It was evaluated for the Ritm-05 complex according to the "Industrial Method of Determining the Cost Effectiveness of Introduction of Industrial Robots." The basis for calculations was data on the third year of production in a pressing plant. One robot contributes an annual saving of 6884 rubles and returns the investment within 1.2 year, requires an additional break-in expenditure of 20,206 thousand rubles but reduces the overall production cost by 16,798 thousand rubles. Figure 1, references 5 Russian.  
[118-2415]

## USING UNIVERSAL-15.03 INDUSTRIAL ROBOT TO AUTOMATE HOT DIE STAMPING

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 19-20

KUZNETSOV, I.Ye., SHEPELEV, M.A. and YUGOV, S.G.

[Abstract] The four basic requirements for robotization of hot stamping processes are proper weight distribution of processed parts to match the robot's capability, ability of the robot to execute repetitive operations, which include loading and unloading, adequate positioning accuracy, and adequate capacity of adequately programmed control hardware. These requirements have been met in development of the Universal-15.03 robot, as confirmed in its qualifying operation with a multiplunger press of 10 MN capacity. The robot grips a blank part from a hopper, transports it first to an induction furnace for heating and then to the press. The job of vertical translation is indirectly handled by fixation of several positioning points in short steps

along a more intricate trajectory. The robot next releases the tong and retracts its arm to clear the press, then transports the finished part to a bin. Pilot operation has revealed that a worthwhile modification of the differential head in the manipulator would be elimination of the unnecessary wrist twisting and use of the corresponding drive for translatory vertical or horizontal motion of the tong instead. Figure 1, tables 2.  
[118-2415]

UDC 621.7.077

#### INDUSTRIAL ROBOTS OF INTEGRATED CONSTRUCTION

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 14-19

KRIVITSKIY, A.A., MAL'KOV, Yu.V. and VATOLIN, B.I.

[Abstract] There are now two types of integrated-modular industrial robots available and most widely used in industry. Type-I includes MRL and MAPP-10/40 (USSR), PR-02 (Poland), MNI (Electrolux Co., Sweden), Robitus RC (Mitsubishi Co., Japan) with one degree or two degrees of mobility provided by separate functional modules and interfacing of modules to power supply, regulation-distribution system and program control effected through interchangeable power and switching lines. In type-II each degree of mobility is provided by separate modules, each module containing not only a servomechanism but also regulation-distribution equipment as well as position controls, power, switching, and communication lines. Industrial robots of type-I are more economical for forging and pressing operations. A series of such robots is being developed at the Taganrog Design Engineering and Technological Institute of Forging and Pressing Robotics, cyclic-duty pneumatic-drive machines with load capacities of 1.25, 2.5, 5.0, and 10 kg respectively. Their basic modules are hand, lifter, robot rotator, base, tong twister, tilter, and pneumatic drive. Figures 7, tables 6.  
[118-2415]

UDC 621.7.077.01

#### NEW STAGE IN ROBOTICS DEVELOPMENT

Moscow KUZNECHNO-SHTAMPOVOCHNOYE PROIZVODSTVO in Russian No 1, Jan 84 pp 13-14

SHIFRIN, Ya.A., holder of USSR state prize, member of presidium, scientific-procedural council to Moscow Municipal Office of CPSU on problems of building and utilizing automatic manipulators (industrial robots) in Moscow enterprises and organizations

[Abstract] While the number of industrial robots operating in the instrument manufacturing industry is to increase to 40,000 during the Eleventh Five-Year-Plan, robot complexes will soon be commercially built for hot stamping of

items up to 6.3 kg and 40 kg in weight. An important factor facilitating this trend is changeover to flexible production systems with attendant improvement of productivity and cost effectiveness, in terms of capital outlays for construction and installation. The scientific-procedural council to the Moscow Municipal Office of the CPSU on building and utilizing automatic manipulators (industrial robots) in Moscow enterprises and organizations, under the leadership of its secretary L.A. Borisov, is overseeing this transition and is enlisting the efforts of appropriate scientific research institutes and design offices to ensure that it proceeds most efficiently and reliably.  
[118-2415]

UDC: 621.822.572

#### NON-CONTACT HYDROSTATIC BEARINGS

Moscow MASHINOSTROITEL' in Russian No 12, Dec 83 p 19

SHIMANOVICH, M. A., candidate of technical sciences and SHCHERBAKOV, V.P.

[Abstract] By eliminating contact between working surfaces, hydrostatic bearings improve the precision and output of the polishing process, as well as the quality of polished articles. The superior damping capacity of hydrostatic bearings makes it possible to relax the requirements for the polishing wheels and their balancing at speeds of up to 120,000 rpm, as well as to increase the service life of the grinding wheels and truing diamond tools. Series production of high power automatic grinding machines with hydrostatic arbor bearings and shaft guides has been initiated. A description is provided of the typical construction of hydrostatic guides 2-3 meters long for tables weighing several tons.  
[120-6900]

UDC 007.52

#### CONTROL OF MOTION OF MANIPULATOR ROBOTS ON BASIS OF FIRST-ORDER KINEMATIC ALGORITHMS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 83 (manuscript received 18 Mar 83) pp 46-52

KRUT'KO, P.D., doctor of technical sciences, professor, and LAKOTA, N.A., doctor of technical sciences, professor

[Abstract] Servomechanisms with kinematics describable by the equation  $X(t) = F q(t)$  ( $X = \|x_1 x_2 x_3\|^T$  and  $q = \|q_1 q_2 q_3\|^T$ ) are considered for controlling the motion of manipulator robots. The vector function  $F|q(t)|$  of kinematic variables  $q$  characterizing the relative positions of mechanism components is assumed to determine  $X(t)$  uniquely at any instant of time and to have partial derivatives with respect to  $q$ . First an algorithm of motion control is synthesized which will transfer the manipulator tong from its initial position into the vicinity of its target position along a straight trajectory

in uniform motion. The corresponding control law and program equations feature a velocity jump at time  $t = 0$ . If desirable, this velocity jump is avoided in algorithms of nonuniform-motion control. A typical such algorithm is one with acceleration from zero to maximum velocity and subsequent deceleration to zero velocity. The servomechanism structure must be modified accordingly by addition of a second feedback loop. The necessary gain is determined and calculated in each case conventionally on the basis of speed and accuracy considerations. The principle can be extended to algorithms and servomechanism structures for control of motion along arbitrary nonrectilinear trajectories. This is demonstrated on the case of trajectories describable by continuous and differentiable functions. Figures 3, references 7 Russian.

[133-2415]

UDC 621.313.13.001.5

#### ELECTRIC MOTORS WITH ELASTICALLY MOUNTED ROTORS

Moscow ELEKTRICHESTVO in Russian No 9, Sep 83 (manuscript received 27 Jan 83)  
pp 29-34

BUT, D.A. and KULIKOV, N.I., Moscow

[Abstract] The concept underlying a bearingless motor with an elastic mounting for the moving element (rotor) is that the rotor is clamped and held by the flexible support so that it can execute cyclical motions powered by the electromagnetic forces. Such motions can be coupled to the load as a torque, alternating linear force or some force acting along a more complex trajectory. The problem of replacing the shaft bearing assembly with a support that experiences a complex periodic deformation is considered to be solved, since there are a large number of devices such as flat springs, bellows, elastic shock absorbers, diaphragms and seals which have been developed for such purposes. This paper initially analyzes motors with a conical motion of the shaft suitable for applications in mixers, medical equipment and robotics. The rotor is made in the form of a disk with a ferromagnetic active region and a shaft running through the center of the disk. The free end of the shaft is connected to the mechanical load. The rotor is held by a flexible support, which is a rubber bushing, bellows, coiled spring, etc. The magnetic cores with the windings are arranged around the stator periphery, adjacent to the end faces of the disk at axial working gaps. The upper and lower cores are mounted on a common steel frame. The windings are powered through controlled rectifiers, switched so as to drive the disk to oscillatory wave-like motions. Various configurations of such motors are discussed and analytical expressions are derived for disk acceleration, r.p.m. and average magnetic force on the disk. The theory is illustrated with sample calculations for an approximately 30 W motor running at 600 r.p.m. with an efficiency of 0.576 weighing about 8 kg. A prototype motor was built to these specifications, using a conventional vacuum rubber bushing as the flexible support. An experiment performed to determine losses in the support found the losses to be 10 to 15 times smaller than the characteristic specific losses in the motor windings. Such

experiments confirm the validity of neglecting the influence of energy dissipation in the support for speeds of less than  $10^3$  r.p.m. Another bearingless pump motor is described; it was used as a perfusion pump for an auxiliary blood circulation apparatus. The service life of the motor is estimated at about 300 hrs at 10 r.p.m. and 3,000 hrs at 1 r.p.m.. The elastic support is approximately 10 times less expensive than a bearing. Another argument in favor of flexible supports is the degradation of the service life of bearings in certain environments. The application of such supports to a conventional single-phase induction motor in which the rotor and stator are coupled by an elastic element allowing the rotation of the rotor forward and backward with a limited travel is also discussed briefly. Figures 5, references 17 Russian. [125-8225]

UDC 62-83-52

#### OPTIMAL CONTROL OF ELECTRIC DRIVE WITH SIMULTANEOUS CONTROL INPUTS FOR MOTOR CURRENT AND FLUX

Moscow ELEKTRICHESTVO in Russian No 9, Sep 83 (manuscript received 9 Dec 82) pp 35-38

PANSYUK, V.I., Minsk

[Abstract] The greater control capabilities of microprocessor-based systems have necessitated the derivation of analytical expressions that define the optimal control of dynamic systems, especially positional electric drives, for which the control algorithms are optimal in terms of power losses and power consumption. This paper is a detailed mathematical analysis of the optimal control of a DC electric drive with a variable magnetic flux. Expressions are found for the optimal controller. When this controller uses real time microprocessor control hardware, formulas are also derived for the various portions of the optimal process as well as the logic expressions for the switching of these parts of the process. The resulting optimal process differs from previous determinations in that the braking portion, when a resistance moment is present, contains a free run-down (passive braking) region, before and after which there can be regions of active braking, when the motor produces an electromagnetic moment. In one numerical example of step DC motor control, which is used to compare the optimal process found here with one developed earlier, power losses are found to be reduced by 5.44% with the new process. The entire solution of the problem using the procedure presented here reduces to finding the conditional extremum of some function of several variables whose number is no greater than the dimensionality of the system and does not lead to a boundary value problem. Figures 3, references 10 Russian. [125-8225]

## MANUFACTURE OF HEAVY RUNNERS FOR HIGH-POWER STEAM TURBINES FOR AES

Moscow ENERGO MASHINOSTROYENIYE in Russian No 12, Dec 83 pp 22-26

MYSHKIN, V.S., office manager, and GLUSHKIN, B.M., office manager

[Abstract] In many AES one now installs alongside high-speed (3000 rpm) steam turbines also low-speed (1500 rpm) ones, the latter featuring larger and heavier runners. A welded low-pressure double-flow runner of a K-1000-60/1500-2 (1000 MW) steam turbine, with seven stages in each of the two flow line, weighs 152.5 tons without blades and consists of 14 forged parts made of 25Kh2NFMA steel. A special production area has been set up for the manufacture of such runners with two custom-made welding machines, a 2000 kW furnace, model 1A685 and model KZh1698F1/1699F1 large lathes, a model KU-324 rotary milling machine tool, a blading assembly stand, a coupling stand, and a dynamic balancer. Prior to welding, runner disks and spacers are machined in model 1540/1550 turrets, milling of fishbone slots being one of the most critical operations, while shafts are turned in KZh1699F1 lathes and then all parts are nondestructively inspected for quality control. After welding, the runners are heat treated and finish machined. Runner stages are flange-coupled, with attendant inspection for breaks or bends along the shaftline, the flange holes having been drilled, reamed, and tapped with a special machine tool. Blading assembly is particularly difficult, especially in seventh (last) stage where a blade has an active length of 1450 mm and weighs 51.2 kg, special rigging and equipment being available for insertion of blades into disk slots. Figures 8, table 1, references 2 Russian.

[126-2415]

## ADVANCED METHODS OF MACHINING HOUSINGS OF K-1000-60/1500 STEAM TURBINES

Moscow ENERGO MASHINOSTROYENIYE in Russian No 12, Dec 83 pp 18-20

CHEPELO, K.S., chief technologist, and BLIZNYUK, V.E., office manager

[Abstract] Replacement of conventional machining methods by an advanced technology has radically improved the production of housings for K-1000-60/1500 (1000 MW - 1500 rpm) steam turbines. Two machine tools built by the Novosibirsk "Tyazhstankogidropress" industrial association imeni A. Ye. Yefremov supplement existing lathes, turret lathes, boring machines, drilling machines, planing machines, milling machines, layout blocks, and welding equipment. The process includes preparatory operations, welding, rough machining and finish machining. The model NS-33F2 machine tool is a custom-made one with high-precision gantry movement and digital program control suitable for processing parts up to 12,000 mm long, 7000 mm wide, 2500 mm high held in fixed position. Its advantages are versatility and long life, maximum

operation intensity achieved by simultaneous machining of almost all surfaces, and economy of time achieved by use of special fast-readjustable gang mechanisms for setup, alignment, locking in position, and release. The model NS-69 machine tool is a special-purpose one for rough and finish machining of inside surfaces, its boring bar hinge coupled to the tool spindle for maximum travel of 1500 mm and with interchangeable carriages for bore diameters ranging from 600 to 3800 mm. With these two machine tools, the production cycle for large turbine housings has been reduced by 20-30% with a concurrent improvement of product quality. Figures 4, references 3 Russian.  
[126-2415]

UDC: 621.73

#### FORGING OF LARGE ROTOR BLANKS EMPLOYING TEMPERATURE HETEROGENEITY OF STEEL

Moscow ENERGOMASHINOSTROYENIYE in Russian No 10, Oct 83 pp 20-22

ONISHCHENKO, A. K., candidate of technical sciences and STASHUK, Ye. K., engineer

[Abstract] A technological process developed by the authors, plus forging of rotor blanks from ingots weighing 198-225 tons, have facilitated sufficient forging of the ingot metal and have provided mechanical properties which correspond to the requirements of technical specifications for rotors. Computer solutions of the two-dimensional axisymmetrical problem of transient thermal conductivity during cooling of ingots and blanks provides the temperature distribution, the yield point of the steel and the temperature gradient along the radius of the blank as a function of the cooling time. These functions have made it possible to provide a scientific foundation for the extrusion process by utilizing the plastic heterogeneity of the steel, to develop the temperature regime and to create a forging tool to implement the process. Figures 3, references 4 Russian.  
[129-6900]

UDC: 621.165.002

#### DEVELOPMENT OF PRODUCTION TECHNOLOGY FOR HIGH POWER STEAM TURBINES AT LENINGRAD METAL PLANT

Moscow ENERGOMASHINOSTROYENIYE in Russian No 10, Oct 83 pp 17-19

OGURTSOV, A. P., chief engineer, Leningrad Metal Plant

[Abstract] This article sketches the history of the development of turbine building in the USSR from 1924, when the first 2 MW steam turbine was produced, to the present. The processes involved in turbine building are outlined, including the production of welded components and changes which

have come about in mechanized assembly. Mechanization and automation of production processes are playing important roles. New technology is being implemented for working the exhaust sections of low pressure cylinders; large end and diametric surfaces will soon be worked by high speed milling heads, which will increase productivity. Figures 2, references 5 Russian. [129-6900]



## TURBINE AND ENGINE DESIGN

UDC: 621.224-82

### OSCILLATING TENDENCY OF HYDRAULIC DRIVE IN HYDRAULIC TURBINE REGULATING SYSTEM

Moscow ENERGOMASHINOSTROYENIYE in Russian No 10, Oct 83 pp 10-12

DAVIDSON, B. A., KLYAVIN, L. A. and SOLOV'YEV, V. M.

[Abstract] Tests are conducted on a special stand to identify the basic factors influencing the oscillating tendency of a hydraulic drive, and methods for eliminating oscillations. The main cause of high frequency oscillations in a long pipeline are elasticity of the transmission and (pressure) coupling between the impeller valve and the main valve. These self-sustained oscillations can be eliminated by applying oil under pressure to the aforementioned valves through different pipes. The system becomes more stable when the frequency of the intrinsic oscillations of the elastic bearing is decreased, the overlap of the impeller valve is increased and the width of its edge is decreased. Figures 3, references 3 Russian.  
[129-6900]

UDC 621.165

### K-500-240-4 STEAM TURBINE BUILT AT LENINGRAD METAL PLANT

Moscow TEPLOENERGETIKA in Russian No 11, Nov 83 pp 15-20

RYZHKOV, V.K., engineer, OURTSOV, A.P., engineer, NEZHENTSEV, Yu.N., engineer, and SHKLYAR, A.V., "Leningrad Metal Plant" Industrial Association for Turbine Manufacture

[Abstract] Leningrad Metal Plant is now building the K-500-240-4 steam turbine for the Ekibastuz GRES. It has been designed as an aggregate structure with complete standardization of components and subassemblies so as to reduce the production cost and shorten the installation time. The turbine consists of four cylinders; high-pressure, one intermediate-pressure, and two low-pressure ones. Its nominal speed is 3000 rpm and its power rating is 525 MW, with 540°C - 23.5 MPa initial steam. Its total length is 29.9 m, 47.2 m together with the TVV-500-2EUZ "Elektrosila" electric generator. The high-pressure cylinder contains 5 left-hand flow stages with a K-800-240 regulator

stage and 6 right-hand flow stages, all guide vanes with uniform section, the seamless-forged runner supported on two bearings. It delivers  $299^{\circ}\text{C}$  - 4.248 MPa steam at the outlet. The intermediate-pressure cylinder is a standard K-500-166-1 double-flow one consisting of 11 left-hand flow and 11 right-hand flow stages, some stages with uniform-section guide vanes and some stages with variable-section twisted guide vanes and runner blades, the seamless-forged runner supported on two bearings, a thrust bearing at the front. The low-pressure cylinders are double-flow ones consisting each of 5 left-hand flow and 5 right-hand flow stages, with interchangeable runners on two six-shoe segmental bearings each. Both low-pressure cylinders are connected through a movable coupling. All runners of the turbine are flexible, all vanes and blades are aerodynamically profiled, two cranking devices turning a runner at 4.1 or 30 rpm are available. The thermal system includes an 8-stage rather than the 9-stage K-500-240-2 regenerative feed-water preheater, two mixed-type and two surface-type low-pressure steam preheaters. Both fluidic regulation and lubrication systems are designed for use of OMTI synthetic non-flammable oil or mineral turbine-grade oil. Figures 5, table 1, references 4 Russian. [142-2415]

UDC 621.165

#### DEPENDENCE OF STREAM PATTERN BEHIND TURBINE BLADINGS WITH VARIOUS CONTOURS OF LEADING EDGE ON ANGLE OF ATTACK

Moscow TEPLOENERGETIKA in Russian No 11, Nov 83 pp 58-59

FADEYEV, I.P., doctor of technical sciences, ZASYPKA, T.T., candidate of technical sciences, TSVIKLIS, V.S., engineer, and ZASYPKA, V.T., engineer

[Abstract] In a study of wet-steam turbines and their operating characteristics, the dependence of stream turbulization behind the turbine blading and of the profile drag on the angle of attack was measured and calculated over the  $-30^{\circ}$ - $(+30^{\circ})$  range of angles for turbine blades with three different contours of the leading edge: 1) aerodynamically smooth; 2) eroded and consequently rough; 3) chamfered and consequently erosion resistant. The result, for blades of  $h = 100$  mm height and  $b = 38.8$  mm chord width set at a  $52^{\circ}$  angle with a relative diametral pitch  $t/b = 1.03$  and for two values of the Reynolds number at the entrance,  $5 \cdot 10^4$  and  $2 \cdot 10^5$ , reveal a significant effect of surface roughness on the turbulization pattern. Surface roughness of the leading edge increases the profile drag and thus reduces the efficiency, but decreases the sensitivity to change in the angle of attack. Moreover, both maximum and mean turbulization are lower behind a blade with rough leading edge than behind one with smooth or chamfered leading edge. The results for a blade with smooth leading edge and  $Re = 2 \cdot 10^5$  agree closely with the G.Yu. Stepanov formula. Figures 3, references 7 Russian.

[142-2415]

## DESIGN OF HIGHLY MANEUVERABLE HIGH-POWER STEAM TURBINES

Moscow TEPLOENERGETIKA in Russian No 11, Nov 83 pp 32-36

SAFONOV, L.P., doctor of technical sciences, KUZNETSOV, V.F., engineer, and KOVALENKO, A.N., candidate of technical sciences, "Central Institute of Boilers and Turbines" Scientific-Industrial Association

[Abstract] A review of experience and developments in design and operation of steam turbines of modern fossil-fuel and nuclear electric power plants reveals that reliability, maneuverability, and equipment life rather than maximum economy are the leading performance indicators, and that transient thermal and mechanical action of the ambient medium on turbine components is one of the main factors limiting these performance characteristics. Accordingly, a set of five design principles has been formulated as guideline for further development and construction. 1) Turbines for fossil-fuel electric power plants must be highly maneuverable as well as highly economical, except peak-power (1,500-2,000 h/yr) and semipeak-power (4,500-5,000 h/yr) units running on lower-grade fuel with capacity for many fast startups as overriding performance indicator. 2) Only turbines in nuclear electric power plants can be treated as base-power units, but even they require some degree of maneuverability. 3) Maneuverability and reliability of power turbines will be achieved by reducing the total number of cylinders through combining of high-pressure and intermediate-pressure stages or intermediate-pressure and low-pressure stages, with the low-pressure cylinder having an appropriately higher throughput capacity, by allowing sufficient clearances between cylinders, bearing housings, and foundation for free thermal expansion without axial misalignment, and by supporting the cylinders of the largest turbines directly on the foundation. 4) The design of main turbine components must be based precisely on operating conditions and capacity requirements, with minimum stresses, strains, and absolute as well as relative thermal expansions. Thermal action of the medium on turbine components can be relaxed by lowering the temperature level in the hottest zones, reducing the intensity of heat transfer where freedom of thermal expansion is limited, aiming for a temperature field symmetric with respect to the axes of cylinders, and slowing down the cooling in the hottest zones. 5) Turbines must be equipped with automatic means of inspection, troubleshooting, and optimal control. Implementation of these principles is demonstrated on a few examples such as separate uniflow high-pressure cylinders and intermediate-pressure cylinders, in combined high-pressure intermediate-pressure cylinders with multiple-wall housings and center-tap steam admission, in separate steam cooling, and in special-purpose axial seals. The load maneuver during transient periods is optimum, with respect to response speed, when the thermal stresses in critical turbine components are at maximum allowable level. This is achieved by appropriate control of the steam temperature. One possible algorithm of load maneuvering after startups has been developed, in the form of a universal program applicable to turbines built at the Leningrad Metal Plant. Figures 3, references 9 Russian. [142-2415]

## STUDY AND IMPROVEMENT OF LAST STAGES IN HIGH-POWER STEAM TURBINES

Moscow TEPLOENERGETIKA in Russian No 11, Nov 83 pp 20-24

TERENT'YEV, I.K., candidate of technical sciences, "Central Institute of Boilers and Turbines" Scientific-Industrial Association

[Abstract] The performance characteristics of the steam channel in low-pressure turbine cylinders are analyzed on the basis of relations and corresponding curves which describe how efficiency, exit angle, angle of meridional stream lines, distribution of mass flow over the blade height, and width of the separation zone depend on the relative volume flow rate  $\overline{Gv_2}$  ( $v_2$  - exit velocity), how axial velocity, exit angle, and specific mass discharge rate vary along the radius behind the blades, and how the economy of successive three low-pressure stages (change in efficiency) depends on the ratio of clearance width to blade height. These relations are based on theoretical and test data pertaining to a 300-1200 MW series of turbines with small ratios of medium runner diameter to blade height, typically  $D_m/h_b = 2.5$ , over wide ranges of flow rate and back pressure, using models in 1:3 scale. Taking into account the discrepancy between results of physical and numerical experiment, which does not exceed 10%, guidelines are established for improving the performance by design. Figures 7, references 9 Russian. [142-2415]

UDC 621.165.001.2

## MODELING AND OPTIMIZATION OF FLOW CHANNELS IN HEAT TURBINES

Moscow TEPLOENERGETIKA in Russian No 12, Dec 83 pp 34-37

LAPSHIN, K.L., candidate of technical sciences, Leningrad Polytechnic Institute

[Abstract] A calculation scheme is proposed for design and optimization of flow channels in multistage heat turbines with respect to gas dynamics, supplementing and refining of existing schemes. It is demonstrated on calculations for the basic elementary flow channel components, namely stationary vanes and runner blades. The equations for the velocity triangle, performance characteristics, and stage or cascade geometry are formulated one-dimensionally. Their solution has been programmed on a computer, the main "cut away" procedure for calculating the gas dynamics in any particular design variant being implementable in the mode of "man-machine" dialog and the "search" procedure implementing the relaxation method of Gauss-Euler coordinate-wise steepest descent with some efficiency as criterion functional. The universal program was tested on calculations for axial turbines in a space of eight variables (three angles, five coefficients and exponents). One-dimensional formulation of the design and optimization problem has been found to be compatible with and adequate for algorithms of nonlinear programming. Figures 3, table 1, references 12: 11 Russian, 1 Western. [122-2415]

## DEPENDENCE OF TURBINE PLANT DESIGN ON AES OPERATING MODE

Moscow IZVESTIYA AKADEMII NAUK SSSR: ENERGETIKA I TRANSPORT in Russian No 4, Jul-Aug 83 (manuscript received 15 Nov 82) pp 3-10

IVANOV, A.A., MAY, V.A., NAUMOV, Yu.V. and POPYRIN, L.S., Irkutsk and Moscow

[Abstract] Mathematical models of a steam turbine plant with a thermal power generator in atomic electric power stations had been developed at the Siberian Institute of Power Engineering (Siberian Department USSR Academy of Sciences) for design and performance optimization purposes. On the basis of these models a subsequent study was done on the dependence of turbine plant design on AES operating mode. Analysis and calculations were performed according to a modular procedure which included interfacing the input data array (nominal equipment characteristics) with a model of the low-potential stage. Calculations covered turbine performance under full load, turbine performance under partial loads, capital investment, annual production of electric energy, and per-unit operating costs. Partial loads were treated as fractions of full load, for which corresponding steam rates and feed water rates were calculated in necessary approximation. All calculations had been programmed in FORTRAN for a BESM-6 high-speed computer. Calculations were done for a steam turbine in a 1000 MW AES with water-graphite channel reactor. Four modes of turbine operation were considered: 1) single-stage steam separation; 2) two-stage steam separation; 3) single-stage steam separation and single-stage superheat of fresh or tapped steam; 4) single-stage steam separation and two-stage superheat of fresh or tapped steam. The calculations have yielded the dependence of turbine efficiency and of pressure ratio across the separator on the steam rate, all quantities normalized to full-load conditions, also the dependence of final temperature difference across the low-potential stage, of optimum coolant (water) temperature, of optimum preheater surface and condenser surface, and of over-expenditures on the utilization factor in terms of operating hours in a year. These relations as well as turbine design and operating parameters determined from them indicate that the turbine utilization characteristics largely influence the parameter optimization. Shorter operating periods require higher optimum temperature heads in all system components, while discounting partial-load periods leads to overestimation of turbine installation costs. Figures 6, tables 2, references 3 Russian.

[123-2415]

UDC: 621.438-53

# REGULATION AND OPERATING MODES OF LMZ GT-100 GAS TURBINE INSTALLATION

Moscow ENERGO MASHINOSTROYENIYE in Russian No 1, Jan 84 pp 6-9

RATNER, I. S., candidate of technical sciences

[Abstract] Structures are defined for regulation systems for GT-100 gas turbines which provide optimum partial load conditions and maximum output power by automatically distributing the fuel consumption between the high- and low-combustion chambers. A number of alternative regulation schemes are examined and compared. Figures 3, references 3 Russian.  
[130-6900]

UDC: 621.165.533.6.001.24

# ESTIMATING PROFILE LOSSES IN PLANNING OF AXIAL HEATING TURBINES

Minsk IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: ENERGETIKA in Russian No 9, Sep 83 (manuscript received 9 Mar 82) pp 73-79

LAPSHIN, K.L., candidate of technical science, docent, Leningrad Order of Lenin Polytechnical Institute imeni M. I. Kalinin

[Abstract] Profile losses have been most thoroughly studied in the flat guide vanes of axial turbines under static conditions. Experimental studies have shown the profile losses obtained in rotating models are 1.5 to 2 times greater than the values determined for static conditions. This brings up the problem of creating a method of calculating profile losses in axial turbines during the planning stage. This article develops single-parameter equations for determination of the profile loss coefficient in flat, circular and rotating sets of vanes convenient for use in calculations during the planning stage. Figures 2, references 10: 9 Russian, 1 Western.  
[92-6508]

## RELIABILITY AND DURABILITY OF STEELS FOR TURBINES IN FOSSIL-FUEL AND NUCLEAR ELECTRIC POWER PLANTS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 12, Dec 83 pp 36-38

KHABACHEV, V.M., candidate of technical sciences, MISHCHENKO, L.D., candidate of technical sciences, KIRICHENKO, Ye.P., candidate of technical sciences, and SIDENKO, V.N., candidate of technical sciences

[Abstract] Six grades of steel were evaluated comparatively with respect to reliability and durability for construction of turbines for fossil-fuel and nuclear plants. Two of these steels were standard grade 32KhM1A for runner disks up to 1500 mm in diameter and special grade 25Kh2NMFA (lower carbon content, higher chromium content, nickel and vanadium traces added) for runner disks 1600-3000 mm in diameter. The latter grade has generally better mechanical characteristics, but peripheral liquefaction of sulfur in forgings of this steel produced in acid open-hearth smelters reduces its ductility and requires modification by reduction of the silicon content to 0.1%. Four other steels were standard grades 20Kh1M1F1TR, 15Kh1M1FL and special grades 20Kh3MVF, 25KhM1F for fasteners and housings. All four grades are adequate under specific operating conditions and their characteristics are improvable by initial stress relieving or appropriate heat treatment. Figure 1, references 7 Russian. [126-2415]

## HEAT LIMITATION FOR POWERFUL TURBINE GENERATOR OPERATIONS IN ASYNCHRONOUS MODES

Moscow ELEKTRICHESTVO in Russian No 11, Nov 83 (manuscript received 19 Oct 81) pp 50-52

KHUTORETSKIY, G. M., doctor of technical sciences and KOSACHEVSKIY, V. I., candidate of technical sciences

[Abstract] Asynchronous modes can be studied from the viewpoint of heating of the core lamination stacks by using the flux pattern in the end zone, which is analogous to the same pattern for synchronous modes; this employs the averaged power diagram in the asynchronous mode in relative units. Losses in these end zone in the asynchronous mode exceed those losses in the synchronous mode significantly. Asynchronous operations can be viewed as a de-energization condition from the viewpoint of lamination stack heating. Increasing the unit power leads to more severe restrictions on asynchronous modes. All other conditions being equal, it is best to reduce the short circuiting ratio from the viewpoint of heating of the end-zone construction elements in asynchronous modes. The flux pattern indicates that significantly greater heating should be expected in the asynchronous mode and that continued operation at nominal or near-nominal power is inadvisable. Losses in the rotor barrel do not limit the load or duration of asynchronous modes. These losses can be estimated by using the reduced generalized characteristic  $P_2=f(s)$ . References 5 Russian. [131-6900]

UDC: 621.313.322-81.001.2

ACCOUNTING FOR ABNORMAL MODES IN DESIGN AND OPERATING OF POWERFUL TURBINE GENERATORS

Moscow ELEKTRICHESTVO in Russian No 11, Nov 83 (manuscript received 26 Jan 83)  
pp 13-18

GLEBOV, I. A., academician, DANILEVICH, Ya. B., doctor of technical sciences, MAMIKONYANTS, L. G., doctor of technical sciences and KHUTORETSKIY, G. M., doctor of technical sciences

[Abstract] A number of abnormal turbine generator modes are examined, and ways of accounting for them in the development and operation of turbine generators are characterized. The abnormal modes considered include operations in underexcitation mode, unbalanced operation modes, sudden shortcircuiting, asynchronous operation, and processes which cause severe twisting forces in the turbine generator shafting. Further investigation of external modes which can occur in power systems, and their effect on turbine generators, must be investigated. References 13: 11 Russian, 2 Western.  
[131-6900]

UDC: 621.313.322-81.013.8.016-35.001.24

OPERATING CONDITIONS AND STABILITY OF TURBINE GENERATORS WITH TRANSVERSE CONTROL WINDING ON ROTOR

Moscow ELEKTRICHESTVO in Russian No 11, Nov 83 (manuscript received 15 Jun 83)  
pp 7-12

SOKOLOV, N. I., doctor of technical sciences and KASPAROV, Z. A., candidate of technical sciences

[Abstract] In order to expand the acceptable range of the active power it is proposed that an additional control winding be employed on the turbine generator rotor. This would not require changing the dimensions of the machinery or reducing the power of the longitudinal windings. Generators employing these proposed arrangements are shown to be capable of operating under any active and reactive loads, limited only by heat conditions. Excitation along the longitudinal axis can be regulated by the deviation in the voltage on the terminals; that along the transverse axis can be regulated by the deviation of the angle between the synchronous emf vectors and the voltage on the high voltage buses of the station. Examples of calculations are provided. References 7: 6 Russian, 1 Western.  
[131-6900]



UDC: 531.62

ENERGETICALLY OPTIMAL CONTROL OF PLANAR ROTATION OF SOLID

Moscow IZVESTIYA AKADEMII NAUK: MEKhanika TVERDOGO TELA in Russian No 5,  
May 83 (manuscript received 5 Aug 81) pp 52-53

KORNILOV, V. Yu., Leningrad

[Abstract] A study is made of the optimal control of planar rotation of a solid body in the general case of an undefined number of control moments, using a system of coordinates fixed to the rotating body. The problem is reduced to the isoperimeter variational problem with unsmooth integrand. A theorem is derived describing the properties of the function, which has three successive sections, monotonic increase, constancy and monotonic decrease. References 3 Russian.  
[98-6508]

UDC: 531.8

DYNAMICS AND CONTROL OF MOTION OF JUMPING VEHICLE

Moscow IZVESTIYA AKADEMII NAUK: MEKhanika TVERDOGO TELA in Russian No 5,  
May 83 (manuscript received 24 Dec 80) pp 42-51

LAPSHIN, V. V., Moscow

[Abstract] A study is made of a jumping vehicle consisting of a body and either four or six legs, with the total mass of the legs representing a significant fraction of the mass of the body. Each leg consists of two elements and has two degrees of freedom of movement at the point of attachment of the upper element to the body, one at the "knee." Problems of programmed motion and stabilization of the motion of the jumping apparatus are solved, assuming that the control system reports all phase coordinates of the apparatus when it is resting on the legs, the instantaneous values of coordinates and angular velocities of the body, angles and velocities in the legs when in flight. It is further assumed that the information system produces an approximate model of the terrain in the landing area before take off, then refines it immediately before landing. Requirements for design of the apparatus are

developed in terms of the forces and power which must be developed and limits of applicability of the angular motion stabilization algorithm are determined. Figures 2, references 9: 5 Russian, 4 Western.  
[98-6508]

UDC: 531.383

#### PROBLEM OF GYROSCOPIC STABILIZATION

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 5, May 83 (manuscript received 1 Jun 82) pp 3-7

SOSNITSKIY, S. P., Kiev

[Abstract] Conditions are established for one type of gyroscopically stabilized system under which the gyroscopic forces do not provide stabilization of the system's equilibrium. References 10: 9 Russian, 1 Western.  
[98-6508]

UDC 531.383

#### ESTIMATES OF ERRORS OF A GYROSCOPE STABILIZED PLATFORM

Kiev PRIKLADNAYA MEKHANIKA in Russian No 9, Sep 83 (manuscript received 5 Oct 81) pp 125-128

ZBRUTSKIY, A.V. and BALABANOV, I.V., Kiev Polytechnical Institute

[Abstract] A gyrostabilized platform has a four-frame cardan suspension in which one of the dynamically adjusted gyroscopes placed on the stabilized platform measures the angle of its deviation in the plane of the platform, while the second such gyroscope measures the deviation relative to this plane. The redundant first gyro can be used to correct the system and may also be a closed system itself. This paper studies the errors in the gyro stabilized platform due to the nonperpendicularity of the axes of the cardan suspension of the platform as well as the disbalance of the components and dynamically adjustable gyroscopes. The cumbersome equations of motion for the system are written, neglecting dry frictional forces in the shafts of platform suspension, second order nonlinearities relative to the angular coordinates and their derivatives as well as terms with periodic coefficients which can affect the dynamics of the platform only in narrow ranges of frequency variations at parametric resonances. The results are illustrated with a sample calculation of the stabilization errors and the errors in the determination of the angular coordinates of an object as a function of the imprecision in the manufacturing tolerances for fabrication and assembly. Static disbalance is responsible for the bulk of the platform error. Figures 2, references 4 Russian.  
[111-8225]

## ERRORS IN COMPENSATING FOR IMAGE OSCILLATIONS BY MEANS OF A GYROSCOPIC HEAD

Moscow TEKHNIIKA KINO I TELEVIDENIYA in Russian No 12, Dec 83 pp 22-24

TOROCHKOV, A.V., Moscow Advanced Engineering School imeni N.E. Bauman

[Abstract] Gyroscopic systems can be used to compensate the shifts of an image on motion picture film due to oscillations of the camera. The major task of such correcting systems is the measurement of the natural oscillations of the motion picture camera and the appropriate compensating rotations of the optical elements based on these measurements, so as to cancel the motions of the camera itself. This paper analyzes the error occurring when compensating for image oscillations as a function of the camera system parameters by introducing the concept of a compensation function. This function is expressed as the ratio of the function describing the harmonic motion of the gyroscope to a similar function for the harmonic oscillations of the camera. The theoretical treatment is illustrated using the transfer function of the gyroscopic compensation system manufactured by the "Arnold and Richter" company. The compensation function is plotted in turn as a function of the frequency of the harmonic oscillations of the image for various values of the time constant,  $t$ , in the transfer function of the correcting system. The graph indicates that actual compensation for image oscillations begins at frequencies of  $1/(10t)$ . This result is in good agreement with operational studies of such compensating gyroscopic systems. Figure 1, references 2 Russian. [116-8225]

UDC: 621.384.6(088.8)

POWER CAPACITIVE COUPLING OF ACCELERATING RESONATORS WITH HF GENERATOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 55, No 4, Oct 83 (manuscript received 24 Jan 83) pp 249-251

PANASYUK, V. S., SAMOSHENKO, Yu. K. and SIMANOVSKIY, M. F.

[Abstract] The characteristics of power capacitive coupling and specific designs of ion and electron accelerators based on it are described. The accelerators described are portable and provide a basis for the production of accelerators for use in the economy. An electron accelerator of this type is an x-ray machine with a resonator-based vacuum increasing transformer. The use of capacitive coupling in accelerating resonators with relatively high mean reactive power is discussed. Photographs of a proton accelerator are presented. Figures 5, references 10: 9 Russian, 1 Western.  
[104-6508]

UDC: 535.312

SIGHTING WITH A NONMOVING DIAPHRAGM

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84 (manuscript received 24 Oct 81) pp 48-51

SIVTSOV, G. P. and RYABCHIKOVA, L. V.

[Abstract] Instruments in which enlargement of the field of vision is performed by changing the direction of the sighting axis are quite common. The optical hinge used to change the sighting axis usually is a reflecting prism or plane mirror. This article discusses sighting using a nonmoving diaphragm and optical hinge of this type. The system of equations derived in the article is used to demonstrate that the hinge must move not only in rotation but also in translation in order to increase the range of angles which can be accommodated. Two examples are discussed as illustrations. Figures 3, references 3 Russian.  
[89-6508]

UDC: 535.361.2

# SCATTERING INDICATRICES OF REFLECTING LIGHT SCATTERING GLASSES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84  
(manuscript received 19 Jan 82) pp 31-34

VOYSHVILLO, N. A.

[Abstract] An approximate empirical analytic approximation of the scattering indicatrices of radiation reflected by specimens of MS20-ONS1, ONS2, ONS3 and ONS4 glass with polished surfaces with various incident angles of the beam is presented based on experimental results. The scattering indicatrices were measured in the plane of the optical axis of the incident beam perpendicular to the surface of the specimen. The quantity determined was the brightness coefficient  $\beta$  at  $\lambda = 550$  nm. Measurement of the brightness factor for various values of  $\beta$  and  $\alpha$  allows comparison of the brightness factor with a change in angle of observation or incident angle. Figures 3, references 4 Russian.

[89-6508]

UDC: 538.822.778.42:535.317.1

# MICROPROJECTION DEVICE WITH HOLOGRAPHIC SCREEN

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84  
(manuscript received 3 Dec 82) pp 27 29

ASTVATSATUROV, A. V., GAL'PERN, A. D., DEMCHENKO, P. I., PARAMONOV, A. A.  
and TYUTIKOVA, I. N.

[Abstract] One method of decreasing visual fatigue when working with a microscope is projection of the image onto a translucent screen, usually matte glass, light-scattering synthetic film, etc. Stereoscopic projection is used to provide an impression of depth. Fresnel lenses are used to collect light. To eliminate the shortcomings of these existing devices, a microprojection device has been developed in which the light-scattering screen is a hexagonal lens array of elements spaced at 0.2 mm with a focal length of 0.8 mm. The optical system of the microscope and two Schmidt prisms create left and right images which are projected onto the screen. A raster screen converts the output spot of the projection system into two monocular zones of observation, each 50 mm in diameter at a distance of 250 mm from the screen. The zones are separated by about 60 mm. The operator can move somewhat while maintaining a stereoscopic view of the object beneath the microscope.

Figures 4, references 3 Russian.

[89-6508]

UDC: 535.317.64

METHODS OF DECREASING INFLUENCE OF DISTORTION OF TELESCOPIC LENSES ON ANGLE MEASUREMENT ERROR

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84  
(manuscript received 27 Mar 83) pp 1-4

VUSTENKO, V. I., GOLUBOVSKIY, Yu. M. and SMIRNOV, S. Ye.

[Abstract] Methods are studied for decreasing the influence of distortion of telescopic lenses on the error of measurement of the rotation angles of an object in order to expand the range of angles which can be measured. It is assumed that the optical axes of the two telescopic lenses used in the system, in which the second telescopic lens is used to cancel the beam rotation of the first, are parallel. Methods include increasing the aperture of the second lens, manufacture of lenses from a material with the highest possible index of refraction, displacement of the collimator slot used to detect rotation along the optical axis and selection of the optimal placement of the two lenses. The basic equations describing the relationships among parameters of the angle measurement device are presented. Figures 4, references 5 Russian. [89-6508]

UDC: 662.997:537.22

MEASUREMENT OF OPTICAL-POWER CHARACTERISTICS OF REFLECTING SURFACES OF MIRROR CONCENTRATING SYSTEMS

Tashkent GELIOTEKHNICA in Russian No 6, Jan 83 pp 22-26

ABDURAKHMANOV, A. A., ZAKHIDOV, R. A., NISHANBAYEV, A. and PANOV, P. A.

[Abstract] Methods for testing the power characteristics of mirror concentrating systems are systematized. In the calorimetric method, the amount of heat transferred by the reflecting surface of the calorimeter to the heat medium is measured; photometric methods for investigating mirror concentrating systems are investigated, and their optical-energy characteristics are described. The method can be used to assess the power capability of concentrating systems; testing of system elements makes it possible to investigate and perfect shaping technology. Figures 3, references 4 Russian. [107-6900]

## METHOD OF REPRODUCING A DEFLECTION ANGLE USING A MODULATION-INTERFERENCE SPECTRUM ANALYZER AND A DISCRETE STEP DRIVE

Moscow IZMERITEL'NAYA TEKHNIKA in Russian No 12, Dec 1983 Abstract pp 22-24

KIRICHENKO, N.A., KORNEYEVA, T.V., IVANOV, B.I., LOPATIN, A.I.,  
RAKHOVSKIY, V.I.

[Abstract] A method of reproducing given deflection angles of monochromatic components of a sample radiation source by using a modulation-interference spectrum analyzer (MISA) and discrete step drive is proposed. These components are diffracted at angles corresponding to certain of their wavelengths. Input parameters for the MISA spectrometer are selected wavelengths of the monochromatic components. Outputs are the corresponding deflection angles of the scanning mirror axis of the spectrometer of the MISA which is the mechanical output of the deflection angle set point adjustment. Accurate wavelength determination results in high accuracy of the deflection angle. A graduated spectral rule is used in connection with an encoded spectral interval of known length. By measuring the number of discrete steps of the drive any arbitrary angle can be determined and reproduced. This system is thus a "code to deflection angle" type converter. Figure 1, references 5: 4 Russian, 1 Western.  
[101-9424]

## HOLOGRAPHIC LENS FOR OPTICAL CORRELATOR

Leningrad OPTIKA I SPEKTROSKOPIYA in Russian Vol 55, No 5, Nov 83 (manuscript received 15 Mar 82) pp 945-949

SEMENOV, G.B., KORESHEV, S.N., PAVLOV, A.V. and SHUBNIKOV, Ye.I.

[Abstract] Aberrations in holographic optics place limitations on the information capacity of the data that can be processed by holographic optical correlators. Nonetheless, the aberrations can be reduced sufficiently for an extensive class of devices such as those for real time data input using space-time light modulators and a TV channel. Typical frame window sizes in such devices do not usually exceed  $20 \times 20$  mm and the maximum spatial frequency is 15 to  $20 \text{ mm}^{-1}$ . This paper analyzes the aberrations of holographic lenses, demonstrating the feasibility of an off-axis lens for correlation image analysis with aberrations similar to an axial lens. A requirement that the wave aberrations not exceed a quarter-wavelength was placed on the lens. Equations are solved for coma and astigmatism, and used to plot the maximum wave aberrations as a function of the spatial frequency of the proposed signal for three cases: 1) normal propagation of a diverging beam and oblique propagation of a plane beam; 2) oblique propagation of diverging and parallel

beams, symmetrical with respect to the normal to the photographic plate; 3) oblique propagation of the diverging beam and normal propagation of the parallel beam. The angle between the beam axes was  $45^\circ$  in all cases, with a lens focal length of 350 mm and an aperture of 32 mm. A schematic drawing of a correlator with an entrance frame of 20x20 mm and a maximum spatial frequency of  $15 \text{ mm}^{-1}$  for the processed signals shows the ray path passing through the input image, impinging obliquely on the holographic lens, which focuses the rays on a matched filter, through which laser radiation shines on an objective for a second Fourier transform, in turn focusing the radiation on the photodetector. The correlation signal is plotted as a function of the displacement of an image fragment in the input frame for three spatial frequencies of the filter: 1) up to  $5 \text{ mm}^{-1}$ ; 2) up to  $15 \text{ mm}^{-1}$  and 3) up to  $36 \text{ mm}^{-1}$ . Performance is satisfactory at frequencies up to  $15 \text{ mm}^{-1}$ . Invariance to displacement of the input image is degraded with an increase in the working spatial frequencies, though within the design band of the lens up to  $15 \text{ mm}^{-1}$  it functions satisfactorily and the change in the correlation signal over the field is insignificant. Figures 4, references 6: 2 Russian, 4 Western. [121-8225]

UDC 621.373:535

# IMPACT OF OPTICAL INHOMOGENEITY IN SINTERED INTERFACE BETWEEN GLASSES ON LASER EMISSION CHARACTERISTICS

Leningrad OPTIKA I SPEKTROSKOPIYA in Russian Vol 55, No 5, Nov 83 (manuscript received 5 Nov 81) pp 940-944

MURZIN, A.G., SOLDAKOVA, N.A., FROMZEL', V.A. and TSVETKOV, A.D.

[Abstract] Glasses can be bonded together by heating the contact surfaces (so-called sintering) to form a monolithic structure. The resulting sintered interface between the glasses, when used in a laser cavity, naturally has an impact on laser performance. This paper details an experimental study of the influence of the optical inhomogeneities produced during the sintering process in the interface on the spatial and energy parameters of neodymium laser emissions when the sintered boundary is located inside the cavity perpendicular to its optical axis. Three samples of phosphate glass 10x20x30 mm with coefficients of thermal expansion of about  $3 \cdot 10^{-7} \text{ }^\circ\text{K}^{-1}$  were prepared by sintering together two pieces at a viscosity of  $10^9 - 10^8 \text{ P}$ . Following the polishing of the outer surfaces of the samples, the deformations of the sintered surfaces were determined using a Mach-Zehnder interferometer. Photographs of the interference patterns from the interfaces clearly show various maximum deviations from the desired surface of between 0.32 mm and 1.6 mm, due to optical inhomogeneities. Data from the placement of the glasses in the neodymium laser cavity are used to plot the output energy as a function of the angular divergence of the beam for various inhomogeneity sizes. Two kinds of optical inhomogeneities can be produced in the interface during sintering: small-scale ones, related to the presence of dust particles, inclusions, etc., which lead to general deformation of the surface and produce a gradient of the index of



refraction, and large scale inhomogeneities, related to the plastic deformation of the glass being joined, as well as to the imprecision of the preliminary polishing of the glass surfaces. In order for an optical inhomogeneity to have practically no impact on the beam angular divergence or laser power, the glasses sintered together should have indices of refraction differing by no more than  $10^{-3}$  (preferably, the difference should not exceed  $5 \cdot 10^{-4}$ ). The difference in the coefficients of thermal expansion of the glasses should be less than  $5 \cdot 10^{-7} \text{ }^{\circ}\text{K}^{-1}$  to achieve the maximum immunity to laser emissions. The authors are grateful to O.S. Shchhavelev for his useful discussions and attention to the work. Figures 3, references 9: 8 Russian, 1 Western. [121-8225]

UDC 535.853.21

# MIRROR ACCESSORY FOR LINE STRAIGHTENING IN DIFFRACTION SPECTROMETERS

Alma-Ata IZVESTIYA AKADEMII NAUK KAZAKHSKOY SSR: SERIYA FIZIKO-MATEMATICHESKAYA in Russian No 6, Jun 83 (manuscript received 21 Dec 82) pp 76-79

KEL'MAN, V.M. and RODNIKOVA, I.V., Institute of Nuclear Physics of the KazSSR Academy of Sciences, Alma-Ata

[Abstract] Spectrometers with diffraction gratings have the inherent defect of bending the spectral lines, which is due to the oblique path of the rays from the portions of the slot source above and below the optical axis of the system. This distorting curvature can be substantially reduced by means of incorporating in the optical path an accessory for the grating, which takes the form of a telescopic system of two cylindrical mirrors. In the case of a monochromator with a plane grating, the plane of symmetry of both of the cylindrical mirrors, parallel to their generatrices, and the main cross-section of the grating are collocated and form the central plane of the monochromator, which coincides with the plane of a drawing showing the ray paths. Analytical expressions are derived for the rectification of the ray paths and applied in a sample calculation to a monochromator in which the diffraction grating was rotated through  $30^{\circ}$  and had 1,200 lines/mm; the telescopic system of cylindrical mirrors consisted of a convex mirror ( $f = 210 \text{ mm}$ ) and a concave mirror ( $f = 280 \text{ mm}$ ). Precise calculations of the curvature of the lines are summarized in tabular form for two cases: 1) the mirror accessory is fixed relative to the collimator; 2) the accessory rotates relative to an axis parallel to the axis of rotation of the grating simultaneously with the rotation of the grating. The mirror accessory with a rotating mechanism providing for matched rotation of the grating and attachment reduces the path deflection of the rays by two orders of magnitude throughout the entire spectral range of the monochromator. If the position of the attachment is fixed, there are limitations on the line straightening, though the curvature can be reduced by a factor of at least five. Figure 1, table 1, references 3 Russian. [115-8225].

## OPERATION OF AN AUTOTRACKING SYSTEM IN VARIOUS VIDEO PLAYBACK MODES

Moscow TEKHNIKA KINO I TELEVIDENIYA in Russian No 12, Dec 83 pp 43-47

SOSHNIKOV, V.G., FRIDLYAND, G.V. AND FRIDLYAND, I.V., All-Union Scientific Research Institute for Television and Radio Broadcasting

[Abstract] Video tape recorders using oblique line scanning heads have the capability of accelerating or slowing down the playback relative to the nominal speed. The video signal quality is determined to a considerable extent by the operation of the autotracking system (ATS). The basis of the ATS is the circuitry which matches the trajectory of the magnetic playback head on the tape surface with the recorded line at the nominal playback speed. This so-called nominal playback matching circuit must incorporate additional devices to speed up or slow down the playback. This paper is a detailed discussion of a video tape recorder ATS developed at the All-Union Scientific Research Institute for Television and Radio Broadcasting. Block diagrams of the system and its components are supplemented with traces of the various control voltages and circuit responses, as well as a drawing of the trajectories of the magnetic head for various special effect modes. A piezoelectric transducer is used to shift the head relative to the record track to produce stop-field, stop-frame or other special effects. It is indicated that such VTR ATS circuits are capable of slowing or accelerating the playback by a factor of 5 to 10 times the nominal speed. The lengthy functional description of the circuits does not however provide any performance specifications for the equipment. Figures 7, references 7: 6 Russian, 1 Western.  
[116-8225]

APPROXIMATE SOLUTION OF THE PROBLEM OF FLUID OSCILLATIONS IN CAVITIES OF  
REVOLUTION

Kiev PRIKLADNAYA MEKHANIKA in Russian No 9, Sep 83 (manuscript received  
5 Aug 81) pp 91-95

SHETUKHIN, V.L. and SHMAKOV, V.P., Moscow

[Abstract] A vessel is formed by a surface of revolution having an axis of symmetry collinear with the gradient of the mass force field. This cavity is partly filled with fluid. This paper develops an efficient approximation algorithm for determining the natural frequencies and modes of the fluid oscillations, including the higher harmonics. The solution applies to cavities with considerable elongation and those in which the free surface area falls off as the relative fluid depth increases. The approach is illustrated with an analysis of the fluid oscillations in spherical, conical and cylindrical cavities with spherical bottoms. The treatment of these cases shows that the method has good computational stability and applies to cases when the free surface of the fluid is smaller than the wetted surface of the cavity. For cavities in which the free surface area decreases with an increase in the relative fluid depth, the method can be used to find the upper and lower bounds of the true values of the natural frequencies; for cavities in which the free surface increases with an increase in the relative depth of the fluid, the approximation converges towards the upper bound. When the free surface is constant, the system of base functions converges to the upper bound, and the lower bound can be found from correcting approximations. Figures 5, references 9 Russian.  
[111-8225]

## TURBULENT FLOW OF FLUID NEAR TRAILING EDGE OF PLATE IN STREAM AT ZERO ANGLE OF ATTACK

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 6, Jun 83 (manuscript received 16 Jul 82) pp 17-23

VELICHKO, S.A. and LIFSHITS, Yu.B., Moscow

[Abstract] The problem of turbulent flow at the trailing edge of a plate, in a stream of incompressible fluid at zero angle of attack, is solved by the method of asymptotic expansions and their collocation. Boundary conditions of adhesion are replaced with the condition of axial symmetry in the wake, which results in a different gradient of the displacement thickness and a longitudinal pressure gradient so large as to invalidate the boundary-layer approximation. A theory is constructed that describes the interaction of wake and boundary layer, with the former assumed to be the only source of perturbations in the latter. The velocity field, its longitudinal and transverse components, as well as the pressure field and the turbulent shearing stress are calculated from the corresponding differential equation of momentum for the appropriate boundary conditions, taking into account that the flow function is antisymmetric in the wake region and assuming a power-law velocity profile in the unperturbed state. The solution is sought in self-adjoint form, with a Fourier integral, and found to contain Gauss's hypergeometric function, which can be evaluated with the aid of the Goursat quadratic transformation. Figures 2, references 15: 5 Russian, 10 Western. [140-2415]

## OPTIMUM GEOMETRY OF INTERBLADE PASSAGES IN IMPELLERS OF TURBOMOLECULAR VACUUM PUMP

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 12, Dec 83 (manuscript received 16 Jun 83) pp 66-69

DEMIKHOV, K.Ye., candidate of technical sciences, docent

[Abstract] Certain performance parameters of turbomolecular vacuum pumps, namely the maximum pressure ratio  $\tau_{\max}$  at equal opposing molecule fluxes and the maximum probability of molecule transfer of suction  $K_{\max}$  under equal pressures on both sides, depend largely on the geometry of the interblade passages in the impellers. A composite universal relation has been established for determining the slant angle of interblade passages or blade generatrices as well as the relative aperture or closure of the passage exit section. This exponential relation between pressure ratio  $\tau$  and probability of molecule transfer  $K$  is  $\tau = a e^{bK} + c$ , where the empirical constants  $a, b, c$  are determined from known or given  $\tau_{\max, n}$  and  $K_{\max, 1}$ . This relation is based

on exact solution of the problem of minimizing the number of impellers  $n$  and optimizing the interblade passages on the suction side 1. Figures 2, references 2 Russian.  
[149-2415]

UDC 534.213

ATTENUATION OF SOUND DURING PASSAGE THROUGH SMOOTH ADAPTER BETWEEN TWO PIPES

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 12, Dec 83 (manuscript received 23 May 83) pp 26-30

GUZHAS, D.R., candidate of technical sciences, docent

[Abstract] The sound pressure in a smooth adapter between two pipes of different uniform diameters is calculated from the corresponding one-dimensional equation of simultaneous gas flow and sound wave through a variable-section pipe. The steady-state version of this equation for a constant frequency of gas oscillations has generally variable coefficients, but assuming an axisymmetric exponential profile of the transition segment reduces it to one with constant coefficients. The profile of sound pressure, exponential along the pipe and a superposition of two components with different space constants within the transition segment, yields the pressure transmission coefficient and the sound isolation parameter inversely related to it. An analysis of its frequency characteristics reveals a critical frequency below which it increases monotonically as the frequency decreases and above which it oscillates about a decreasing level as the frequency increases. Figures 2, reference 1 Russian.  
[149-2415]

UDC: 533.601.312

FLOW AROUND ROTATING AND NONMOVING CIRCULAR CYLINDER NEAR FLAT SCREEN.  
REPORT 1. AERODYNAMIC FORCES IN CYLINDER

Novosibirsk IZVESTIYA SIBIRSKOGO OTDELENIYA AKADEMII NAUK SSSR: SERIYA  
TEKHNICHESKIKH NAUK in Russian Ser 3, No 13, Oct 83 (manuscript received  
6 Aug 82) pp 50-59

KOVALENKO, V. M., BYCHKOV, N. M., KISEL', G.A. and DIKOVSKAYA, N.D.,  
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of Sciences, Novosibirsk

[Abstract] Results are presented from an experimental study of the major aerodynamic characteristics of a rotating and a nonmoving circular cylinder near a flat screen, primarily in the area of critical Reynolds numbers. The work consists of three parts. In the first report (this report) results are

presented from measurement of aerodynamic forces on the cylinder, both rotating and nonrotating. In report two the distribution of pressure, amplitudes and frequencies of pulsations on the surface of the nonmoving cylinder will be presented; in report three the distribution of pressures on the screen and conclusions will be presented. The experimental installation is described and diagrammed. Tests were performed in a subsonic wind tunnel, the ITPM T-324 with a 1 x 1 m cross section and a length of 4 m. The lift and drag of rotating and nonrotating cylinders are computed. It is shown that the aerodynamic characteristics depend in a complex manner on the Reynolds number of the incident streams, relative speed of rotation of the cylinder and distance between cylinder and screen. The presence of this screen resulted in the appearance of a repulsive force between cylinder and screen in addition to the unsteady forces acting on the cylinder at greater distances from the screen. The influence of this screen is most notable at distances of about 0.1 d or less. Rotation of the cylinder changes not only the value and nature of the forces but in some cases even their sign, particularly at critical rotational speeds. Figures 10, references 16: 6 Russian, 10 Western. [96-6508]

UDC: 533.534.115

# PARAMETRIC STUDY OF AUTOOSCILLATION UPON FLOW OF SUPERSONIC JET INTO CYLINDRICAL CAVITY

Novosibirsk IZVESTIYA SIBIRSKOGO OTDELENIYA AKADEMII NAUK SSSR: SERIYA TEKHNIЧЕСКИХ НАУК in Russian Ser 3, No 13, Oct 83 (manuscript received 24 Jul 81) pp 22-26

GLAZNEV, V. N., SOLOTCHIN, A. V. and SULEYMANOV, Sh., Institute of Theoretical and Applied Mechanics, Siberian Branch, USSR Academy of Sciences, Novosibirsk

[Abstract] Studies are made of the oscillations which arise when a supersonic jet flows into a cylindrical cavity, the other end of which is plugged. Previous studies have successfully described the stable shock-wave process within the cavity, but have not explained the mechanism of development of autooscillation nor given the relationship between the gas dynamic structure of the jet and of the wave processes in the cavity. This article attempts to describe the amplitude-phase-frequency characteristics of the autooscillations in dimensionless form. Experiments were performed on an acoustical jet installation at the author's institute, providing a stagnation pressure in the forechamber of up to about  $15 \cdot 10^6$  n/m<sup>2</sup>. The measurement system consisted of optical devices allowing photography of instantaneous flow pictures between the nozzle and the tube plus a measurement and analysis system for determination of pressures and oscillations of pressure in various cross sections of the tube. It was found that the pressure averaged over time of the tube depends only on Ma, the pressure at the end of the tube being equal to the pressure which would obtain a direct shock wave with Mach number before it equal to Ma were in front of the tube. A method is suggested for calculating the amplitude-frequency characteristics of oscillation. Figures 5, references 4: 3 Russian, 1 Western. [96-6508]

## HYDRAULIC DRAG IN ROTATING RADIAL CHANNEL

Moscow IZVESTIYA AKADEMII NAUK SSSR: ENERGETIKA I TRANSPORT in Russian No 4, Jul-Aug 83 (manuscript received 26 Apr 82) pp 143-148

OVCHINNIKOV, O.N., Leningrad

[Abstract] Flow of a viscous fluid through a rotating radial channel with circular cross section is analyzed, the flow being characterized by a Reynolds number much larger than unity and a Rossby number of the order of unity. The drag coefficient is calculated, assuming a uniform longitudinal pressure gradient and a stabilized laminar flow sufficiently far from the channel entrance section. First, flow of an incompressible viscous fluid in the boundary layer is considered the problem being formulated for the corresponding two Navier-Stokes equations with appropriate boundary conditions, then flow in the core region is considered under the same assumptions and on the basis of the corresponding Navier-Stokes equation. The existence of a thin Ekman layer is taken into account. The resulting two approximate relations for the drag coefficient  $\xi$  as a polynomial fractional-power function of the Rossby number are compared with the empirical relation  $\xi = 0.249 Re^{0.9} Re^{0.2}$  and the latter is found to be adequate for practical calculations for the given range of flow parameters. Figures 4, references 12: 6 Russian, 6 Western. [123-2415]

UDC: 532.525.6

## STUDY OF STRESSES ON SURFACE OF FLAT BARRIER IMMERSED IN UNDEREXPANDED JET OF RAREFIED GAS

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA in Russian Ser 19, No 4, Oct 83 (manuscript received 30 Mar 82) pp 78-83

PANOV, B. F.

[Abstract] Results are presented from an experimental study of the pressure and shear stress on the surface of a flat infinite barrier with various conditions of flow of an air jet from a sonic nozzle around the barrier. Increasing the rarefaction of the gas in the underexpanded jet leads to a significant change in flow structure in the shock layer and an increase in the significance of viscous forces. Studies were performed on a low density installation allowing a flow of the gas of  $10^{-4}$  kg/s with a pressure in the receiver of about 1.33 Pa. A diagram explains the method of measurement used. It is found that the value of  $\tau/p_0$  increases with increasing rarefaction and becomes comparable to the relative pressure at great  $\bar{h}$ ; the position of the maximum of the curve  $\tau(r)$  does not change with a change in degree of rarefaction; equations  $\tau_m/p_0 = f_1(p_0)$  are linear in logarithmic scales where  $h = \text{const}$  and have identical slopes for different  $\bar{h}$ . Figures 5, references 8: 7 Russian, 1 Western. [95-6508]

UDC: 532.5:527.141.1

INFLUENCE OF RIVER DRIFT FLOW ON DESIGN OF HYDRAULIC ENGINEERING STRUCTURES

Moscow GIDROTEKHNIЧЕСКОYE STROITEL'STVO in Russian No 1, Jan 84 pp 23-28

SANOYAN, V. G., candidate of technical sciences

[Abstract] This study examines the properties of an open stream maximally saturated with detritus identified on the basis of theoretical and experimental investigations. These properties can be used to develop new designs for hydraulic engineering structures involving the movement of flows carrying detritus. The properties of detritus-bearing flows maximally saturated with solid particles are described, and the properties of such flows are used to analyze and design structures. The materials presented have been recommended for use by design organizations in designing anti-silt structures. Figures 6, references 18 Russian.

[117-6900]

UDC: 621.515

AERODYNAMIC FORCES DEVELOPING IN CHANNELS BETWEEN VANES IN TURBINE DRIVE WHEELS

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 9, Sep 83 (manuscript received 23 Mar 82) pp 79-85

SHPITAL'NIKOV, K. F., doctor of technical sciences, SHPITAL'NIKOV, V. K., engineer, All-Union Scientific Research Institute of Light and Textiles Machine Building

[Abstract] A study is made of the steady flow of an ideal gas in a field of centrifugal forces. A jet theory is used in which the mean absolute velocity of gas flow is determined by a quadratic equation. It is assumed that the angles between the tangential and curved paths are piecewise constant. Solution of the equation of continuity and an Euler system of equations of motion, as well as kinematic and thermodynamic equations for turbine machines, is used to develop the method for determining the aerodynamic forces arising in the channels between the vanes of the drive wheels of the turbine. Figures 3, references 3 Russian.

[92-6508]



## HYPERSONIC NONEQUILIBRIUM GAS FLOW PAST ZERO-ASPECT WING

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 6, Jun 83 (manuscript received 25 May 82) pp 125-128

GOLUBINSKIY, A.I. and GOLUBKIN, V.N., Moscow

[Abstract] Hypersonic flow of a gas stream past a zero-aspect wing is analyzed, taking into account the occurrence of physical and chemical nonequilibrium processes in the gas. The corresponding equations are formulated in the system of coordinates  $x^0 = cx$ ,  $y^0 = c\epsilon \tan \alpha y$ ,  $z^0 = c\epsilon^{1/2} \tan \alpha z$  fixed to the wing. These equations are solved analytically for velocity  $v$ , pressure  $p$ , and the density jump function  $S(x,y)$  by the approximate method of a thin shock layer, considering the conservation of longitudinal vorticity  $\omega_v = \epsilon^{-1/2} \cos \alpha w_y$  along a streamline characteristic of every nonequilibrium flow. A class of particular solutions is obtained, after transformation to the system of independent coordinates  $x,y,z$  and translation of the latter along the  $y$ -axis, with curvature of the wing cross section as parameter. The effect of nonequilibrium on the thickness of the shock layer is found to weaken as this curvature parameter increases. The authors thank V.Ya. Neyland for stimulating discussions. Figures 2, references 7: 4 Russian, 3 Western.  
[140-2415]

## BOUNDARY LAYER AT MOVING CYLINDER SURFACE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 6, Jun 83 (manuscript received 23 Sep 82) pp 38-42

ZUBAREV, V.M., Moscow

[Abstract] The problem of symmetric steady laminar flow is solved for a circular cylinder in a transverse stream of incompressible viscous fluid, considering the case where one part of the cylindrical surface between front and back stagnation points is movable. The corresponding two-dimensional equations of the boundary layer are formulated in dimensionless coordinates  $x, Y = y\sqrt{N_R}$  with dimensionless velocity components  $u, V = v_1\sqrt{N_R}$ . After transformation to Gortler coordinates, they are solved for the velocity profiles and the distribution of frictional stress over the wall. The force and the work necessary for moving a cylinder through a stationary fluid are also calculated on this basis, taking into account hydrostatic pressure as well as hydraulic drag. The author thanks G.G. Chernyy for attentiveness. Figures 5, references 20: 7 Russian, 13 Western.  
[140-2415]

## INTERACTION OF HARD PARTICLE WITH SOUND WAVE IN VISCOUS FLUID

Kiev PRIKLADNAYA MEKHANIKA in Russian No 11, Nov 83 (manuscript received 30 Sep 82) pp 92-99

ZHUK, A.P., Institute of Mechanics, UkrSSR Academy of Sciences, Kiev

[Abstract] A barotropic compressible fluid fills all of the space containing a hard particle. A sound wave propagating in the fluid interacts with the particle. Vector equations are solved to describe the average hydrodynamic forces acting on the particle, neglecting thermal effects and considering that some fluid adhesion is present. The method is based on a simplification of the original system of hydrodynamic equations which preserves both nonlinear and dissipative terms. The approach is used by way of example in the determination of the average hydrodynamic force due to a plane wave sound field acting on a spherical particle with a small radius in a low viscosity fluid. A simple analytical expression is found for the average force on the particle in an ideal fluid along with one which defines the influence of viscosity on this average force. No sample numerical calculations or experimental confirmations are noted in this theoretical treatment. References 11: 10 Russian, 1 Western.  
[133-8225]

## RADIATION FROM NONCIRCULAR CYLINDRICAL SHELLS IN FLUID

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 19, No 8, Aug 83 (manuscript received 28 Oct 82) pp 3-10

VOROB'YEV, S.A. and GUZ', A.N., Institute of Mechanics, UkrSSR Academy of Sciences, Kiev

[Abstract] The general problem of dynamics for an infinitely long noncircular cylindrical shell in a boundless ideal fluid is solved according to the linear theory in the acoustic approximation by the method of boundary shape perturbations. The problem of vibrations is then solved and the radiation of waves is analyzed for such a shell under a load which varies harmonically in time, with the pressure distribution in the fluid satisfying the Helmholtz equation. Numerical calculations and results are shown for a cylindrical shell with elliptical cross section, also for two prismatic shells with rounded edges and a triangular or square cross section respectively. Figures 5, table 1, references 11 Russian.  
[150-2415]

UDC 539.3

PLANE-POLARIZED WAVE DIFFRACTION BY ABSOLUTELY RIGID INCLUSION WITH NONCIRCULAR CYLINDRICAL SHAPE

Kiev PRIKLADNAYA MEKhanika in Russian No 10, Oct 83 (manuscript received 2 Jul 82) pp 119-122

KOLODIY V.I. and SHUL'GA, N.A., Institute of Mechanics of the UkrSSR Academy of Sciences, Kiev

[Abstract] An isotropic elastic medium contains a noncircular absolutely rigid inclusion. A plane longitudinal wave propagates in the elastic medium. This paper analyzes the wave diffraction by the inclusion and studies the distribution of the dynamic stresses as a function of frequency, inclusion shape and direction of travel of the incident wave. The formulation reduces to the solution of an infinite system of algebraic equations which can be solved numerically. Three cases are treated and graphs are drawn to illustrate the stress distribution along the outline of the inclusions: elliptical, triangular and square cross-sections for cases when the wave propagates along the minor axis of the ellipse, impinges on the vertex of the triangle and on a side of the square, as well as when the wave travels along the major axis of the ellipse, impinges on a side of the triangle and a corner of the square. Figures 4, references 6 Russian. [114-8225]

UDC 539.30

MORE PRECISE THEORY OF SHELLS TAKING BENDING OF THE NORMAL INTO ACCOUNT

Kiev PRIKLADNAYA MEKhanika in Russian No 10, Oct 83 (manuscript received 5 Nov 81) pp 66-70

GALIMOV, K.Z. and NEMTSEV, Ye.A., Mariyets State University, Yoshkar-Ola

[Abstract] If a coordinate system fixed to the particles of a continuous medium is used to describe a motion, the coordinate lines will bend over the course of time, deforming along with the medium. Classical shell theories allow the warping of the  $x^1$  and  $x^2$  coordinate lines on the central surface; various hypotheses prohibit the bending of the  $x^3$  axis. The distortion of the  $x^3$  axis can be disregarded in the case of very thin shells. This paper

is a theoretical analysis of a shell which takes into account the elongation and curvature of the  $x^3$  axis, deriving an equation for the migration vector. This vector is not specified, as is generally the case, but is found by integrating Frenet equations and thus is a more general solution. The analysis is applied to sample calculations of the bending of the normal element for circular plates of various thicknesses which are clamped around the periphery. It is shown that for a ratio of the plate thickness to radius of between 0.01 and 0.1, the curvature of the  $x^3$  coordinate axis in the region of the plate outline becomes quite significant. References 3 Russian.  
[114-8225]

UDC 539.3:534.1

# STUDY OF LONGITUDINAL OSCILLATIONS OF VARIABLE SECTION RODS USING A MORE PRECISE THEORY

Kiev PRIKLADNAYA MEKhanika in Russian No 10, Oct 83 (manuscript received 17 May 82) pp 102-105

KSENOFONTOV, A.A., Leningrad Polytechnical Institute

[Abstract] The classical equation for free longitudinal oscillations in a homogeneous changing cross-section rod subject to planar deformation is sufficiently precise at low frequencies, though the error is considerable at high frequencies, since transverse motions become significant. This paper derives more precise equations for these free longitudinal oscillations by using a variational technique based on Reissner's functional applied to the plane deformation case. The solution of the resulting system of ordinary differential equations with variable coefficients is solved by a unique harmonic approximation involving the breakdown of the rod into a number of steps. A sample calculation is used to demonstrate that the error in this harmonic approximation is small and exhibits no tendency to increase monotonically with an increase in the number of breakdown steps. Classical theory significantly overstates the frequency of the third resonant oscillation as compared to the correct value from numerical simulation and this approach. Table 1, references 3 Russian.  
[114-8225]

## STEADY-STATE OSCILLATIONS OF ELASTIC HALF-SPACE WITH HORIZONTAL CYLINDRICAL CAVITY

Kiev PRIKLADNAYA MEKhanika in Russian No 10, Oct 83 (manuscript received 13 Nov 81) pp 111-115

BABESHKO, V.A., SELEZNEVA, T.N., SELEZNEV, M.G. and SOKOLOV, V.P., Scientific Research Institute of Mechanics and Applied Mathematics of Rostov State University, Rostov-na-Donu

[Abstract] Steady-state oscillations are excited and propagated in an elastic half-space containing a cylindrical cavity, with the generatrix parallel to the surface. The system is subjected to an oscillating load applied to the flat and cylindrical surfaces. While the problem of elastic wave diffraction has been studied quite well for this geometry when the cavity does not go out to the surface of the half-space, this paper analyzes the more general case, mathematically describing an arbitrarily deep hole using the example of an antiplanar problem. Equations of motion are written for the antiplanar oscillations of the half-space with the horizontal cylindrical hole employing dynamic Lamé equations. Two cases when the hole is deep are considered: 1) the surface of the half-space is stress free and the shear stresses are specified at the cylindrical surface; 2) uniformly distributed tangential stresses are specified at the surface of the half-space and the cylindrical surface is stress free. The resulting analytical expressions allow the determination of the wave fields excited in the elastic half-space with a cylindrical cutout and various types of loading. The method can be extended to a three-dimensional formulation as well. References 4 Russian. [114-8225]

## STRESSED STATE NEAR HOLES IN SHELLS OF REVOLUTION

Kiev PRIKLADNAYA MEKhanika in Russian No 10, Oct 83 (manuscript received 4 Mar 83) pp 115-119

CHEKHOV, V.N., Donetsk State University

[Abstract] Design calculations for slightly curved shells weakened by holes can be carried out using a number of methods developed at the present time. This paper considers the design of shells with a considerable curvature and weakening holes, based on complex equations from this shell theory. The stressed and strained state of the shell is represented by the sum of the basic state in the shell without the hole and the perturbed state caused by the hole. Homogeneous differential equations are written in terms of the complex translation functions for the perturbed state. The iteration solution is applied to two sample cases: 1) a spherical shell with a hole; 2) a circular cylindrical shell with an oval hole. An exact solution of the

differential equations is found in the first case, while two approximations using the iteration scheme are adduced in the second. Graphs are drawn showing the maximum stresses in the case of axial tension of the cylindrical shell with a circular hole and when the spherical shell is exposed to a uniform pressure. The oval hole is covered with a cap which imparts only the shear force to the edge of the shell. The membrane stresses are plotted in this case as a function of the geometry, showing that with an increase in the thickness of the shell, the influence of the ellipticity of the hole is increased and the difference between this result and the solution for a gently sloping shell increases. Figures 3, references 5 Russian.  
[114-8225]

UDC: 539.3

STRESSED STATE OF TRANSVERSALLY ISOTROPIC CORRUGATED CYLINDER OF FINITE DIMENSIONS

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 38-43

BLOSHKO, N. M.

[Abstract] The author considers an elastic homogeneous transversally isotropic solid cylinder subjected to axisymmetrical lateral and end stresses. The perturbation method is used to reduce the problem to a recursive sequence of boundary value problems for a circular (non-perturbed) cylinder. The problem of the elastic equilibrium of a uniform transversally isotropic solid transversally corrugated cylinder subjected to constant axial stretching-compression is solved. Figure 1, references 8: 7 Russian, 1 Western.  
[112-6900]

UDC: 624.074.4:518.5

OPTIMIZATION OF COMPOSITE CONICAL SHELL REINFORCED WITH RIBS SUBJECTED TO EXTERNAL PRESSURE

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 44-51

RIKARDS, R. B., EGLAYS, V. O. and GOLDMANIS, M. V.

[Abstract] A conical shell with external conical ribs subjected to external pressure is examined. The optimization problem  $G(\bar{x}) \rightarrow \min$  is stated and solved by nonlinear programming. A numerical example of the optimization of a shell is given, indicating the optimum rib height-to-thickness ratio. The method permits the use of the calculated values of critical loads obtained analytically or numerically, as well as experimentally observed critical loads. Figures 3, references 11: 10 Russian, 1 Western.  
[112-6900]

UDC: 539.3

INFLUENCE OF PRESSURE WAVE VELOCITY ON RESPONSE OF CYLINDRICAL SANDWICH SHELL

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 59-64

POZHUYEV, V. I.

[Abstract] The influence of the velocity of the normal axisymmetrical pressure wave on the stress-strain state of a shell is examined. A unique stationary solution is found for any pressure wave velocities of the bearing layers by augmenting the equations with dissipative terms corresponding to damping in the axial and radial directions. Numerical calculations are made for annular and lengthwise exponential by decreasing pressures. The solutions can be used to assess findings obtained when the motion of the sandwich shell is described by approximate equations. Figures 6, references 4: 3 Russian, 1 Western.

[112-6900]

UDC: 539.3

INVESTIGATION OF STRESS-STRAIN STATE OF CYLINDRICAL SHELLS BASED ON EQUATIONS OF THEORY OF ELASTICITY

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 72-77

PANKRATOVA, N. D.

[Abstract] Cylindrical single-layer and sandwich shells assembled from isotropic layers are investigated. The stressed state is analyzed by an exact method of reducing the initial boundary value problem to a one-dimensional problem and then integrating by a stable numerical method. A system of ordinary sixth-order differential equations describes the problem for the case in which the ends of the shell are not offset in their own plane and are free of any normal load. Failure to allow for tangential stresses results in negligible error for the parameters examined; disregarding transverse compression in the zone of the localized mode can result in incorrect findings. Figures 3, references 7 Russian.

[112-6900]

UDC: 624.07:534.1

OSCILLATIONS OF SYSTEMS OF ISOPERIMETRICALLY-COUPLED ELASTIC BODIES

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 98-101

GOROSHKO, O. A. and EL'MANOVICH, S. S.

[Abstract] The problem of the motion of free elastic bodies is reduced to an isoperimetric problem; the isoperimetric coupling is represented by the conditions defining the position of the main central axes of inertia at each moment in time in the system of the formed bodies. The boundary value problem of the oscillations of two free beams reduces to a system of heterogeneous equations. Figures 3, references 4 Russian.

[112-6900]

UDC: 539.3:534.1

APPLICATION OF LYAPUNOV-SCHMIDT METHOD TO INVESTIGATION OF STABILITY AND SELF-SUSTAINED OSCILLATIONS OF COMPLEX MECHANICAL SYSTEMS

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 102-109

VORONTSOV, G. V. and KABEL'KOV, A. N.

[Abstract] The problem of finding critical parameter values, investigating the stability of equilibrium states and self-sustained oscillations of elastic constructions approximated by holonomic mechanical systems with a finite number of degrees of freedom is examined. The critical parameter values are found from linearized perturbed motion equations. The stability of the equilibrium state and self-sustained oscillation is investigated on the basis of the Lyapunov-Schmidt method, and the frequencies and amplitudes of steady state self-sustained oscillations are found in the same way. The deformations of the constructions are assumed to be finite, with small deviations during loss of stability in self-sustained oscillations. The method for finding the critical parameters is an extension of the D-partitioning method to "coupled" problems in which the coefficients of the polynomial describing the equilibrium state depend upon the stress-strain state of the construction in the original equilibrium state. Figures 2, references 7 Russian.

[112-6900]



UDC: 539.3:534.1

PARAMETRIC OSCILLATIONS OF THIN RECTANGULAR VISCOUS-ELASTIC PLATES

Kiev PRIKLADNAYA MEKHANIKA in Russian No 12, Dec 83 pp 120-124

KHOANG-VAN-DA

[Abstract] Parametric oscillations of a thin rectangular viscous-elastic plate resting on a nonlinear elastic base are examined. The Poisson coefficient is assumed to be constant in the derivation of the equation for the oscillations of the plate, and the mechanical behavior of the material during stretching is described by the model of a standard linear body. The nonlinear problem is solved asymptotically; amplitude-frequency characteristics are constructed, and it is demonstrated that the viscous-elastic properties of the material can have a substantial influence on the outcome of the oscillations. Figures 4, references 4 Russian.

[112-6900]

UDC: 531.8

EQUATION OF PLANAR MOTION OF MANIPULATOR ELASTIC ELEMENT

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 5, May 83 (manuscript received 12 Jan 83) pp 33-41

AKULENKO, L. D. and GUKASYAN, A. A., Moscow

[Abstract] A study is made of the controlled motion in plane of the elastic element of a manipulator. The dynamics of the controlled motions of the loaded terminal element of the manipulator are studied by means of a mechanical model of slight bending considering both inertia and the force of gravity. The physical sense of the result is that small, smooth controlling actions cause small elastic oscillations, the influence of which on the control is relatively slight, allowing simplification of the solution of the control problems and a more general statement. It is established that the tasks of kinematic and dynamic control of the motion of an elastic rod by means of concentrated control forces differ considerably. Figure 1, references 16: 15 Russian, 1 Western.

[98-6508]

UDC: 531.384

MOVEMENT OF BODY WITH SHARP EDGE OVER SMOOTH HORIZONTAL PLANE

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 5, May 83 (manuscript received 12 Jul 82) pp 8-16

MARKEYEV, A. P.

[Abstract] A study is made of the movement of a heavy solid body over a nonmoving absolutely smooth horizontal plane assuming that the body has a rib which ends in a sharp edge in the form of a convex curve lying in one of the main central planes of inertia of the body. Only motions such that the body touches the supporting surface on a single point on the sharp edge are studied. It is shown that there are two types of stable motion in which the body rotates at a constant angular velocity around a vertical line passing through its center of gravity. References 16: 10 Russian, 6 Western. [98-6508]

UDC: 531.011

DYNAMIC EFFECTS IN ELASTIC ROTATING RING

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 5, May 83 (manuscript received 8 Apr 83) pp 17-23

ZHURAVLEV, V. F. and KLIMOV, D. M., Moscow

[Abstract] A study is made of a thin ring with symmetrical cross section, considering that bending of the ring occurs only in the plane of the ring. It is assumed that the ring rotates relative to inertial space in its own plane at a speed which varies with time. The specifics of small scale elastic oscillations of the ring are analyzed considering its rotation, constructing the solution to the problem of elastic oscillations by the method of averaging. It is found that the wave field coincides with the wave field of the nonrotating ring but rotates so that the angle of rotation of the field relative to the ring is proportional to the angle of rotation of the ring relative to inertial space. The vibrating ring can thus be considered an inertial information transducer. References 3: 1 Russian, 2 Western. [98-6508]

## BEATING OF ROTOR ON BALL BEARINGS

Moscow IZVESTIYA AKADEMII NAUK: MEKHANIKA TVERDOGO TELA in Russian No 5, May 83 (manuscript received 5 May 81) pp 24-32

GALAKHOV, M. A. and FEDOSOV, B. V., Moscow

[Abstract] Assuming that the only defect in the geometry of a set of ball bearings is differences in the diameters of the balls, a model published in an earlier work is extended to include estimation of the coefficient of viscous friction by means of the elastic-dynamic theory of lubrication. Nonharmonic beating modes at various frequencies of radial and axial oscillations of the rotor are calculated and studied. Equations are derived for the frequency and amplitude of beating and instability of power loss to friction in each of the bearings. Figures 2, references 2 Russian.  
[98-6508]

UDC 539.3:624.074.4

## STABILITY OF ANISOTROPIC CYLINDRICAL SANDWICH SHELLS

Kiev PRIKLADNAYA MEKHANIKA in Russian No 9, Sep 83 (manuscript received 28 Jul 82) pp 14-20

BABICH, I.Yu., GUZ', A.N. and DERIGLAZOV, L.V., Institute of Mechanics of the UkrSSR Academy of Sciences, Kiev

[Abstract] A cylindrical sandwich shell is subjected to a uniform axial pressure. Cumbersome third order partial differential equations are given for such rigid orthotropic shells based on Timoshenko type hypotheses which take into account the transverse shear deformation. The equations also consider the moments due to surface forces on the shell because of the interaction of the shell with a filler. The filler is described by three-dimensional linearized elastic stability equations; it is assumed that the shells are rigidly fastened to the filler and the contact surfaces do not coincide with the center surfaces of the shells. It is assumed that the materials of the support layers and filler have the same coefficient of transverse expansion in the subcritical homogeneous state. The stability of such shells is illustrated by graphs which plot the minimum of a dimensionless critical load parameter as a function of the geometric and mechanical parameters of the shells and filler. The error in the calculation of this dimensionless parameter when the Kirchhoff-Love hypothesis is applied to the external layers of the three layer shell can reach 100%, as contrasted to data obtained using the proposed approach. When the relative thickness of the filler increases, the critical load also increases to a certain point after which there is practically no additional increase. The critical load found from the static hypothesis is less than the corresponding load based on the kinematic theory. Figures 4, references 9 Russian.  
[111-8225]

## FREE WAVE PROPAGATION IN A CYLINDRICAL SANDWICH SHELL WITH A FLUID

Kiev PRIKLADNAYA MEKHANIKA in Russian No 9, Sep 83 (manuscript received 14 Aug 81) pp 32-37

POZHUYEV, V.I., Zaporozh'ye Industrial Institute

[Abstract] An infinitely long cylindrical sandwich shell contains a compressible fluid in which nonaxially symmetric elastic waves propagate. Equations of motion for the support layers are written based on the Kirchhoff-Love hypothesis, taking into account the normal reaction of the filler and the action of the fluid on the internal support layer. These dispersion equations are also written and solved for the case of an ideal fluid and the dispersion curves show the phase velocity of wave propagation for the ideal fluid case, where the supporting layers are steel and the fluid is water with negligible viscosity. Analysis of the axially symmetric case is sufficient to determine the critical velocities when finding the hydrodynamic reaction of the system. This theoretical treatment adduces no experimental data or design examples. Figures 4, references 6 Russian. [111-8225]

## STUDY OF OSCILLATIONS OF COMPOSITE CYLINDRICAL SHELLS USING A DYNAMIC STIFFNESS TECHNIQUE

Kiev PRIKLADNAYA MEKHANIKA in Russian No 9, Sep 83 (manuscript received 9 Jun 81) pp 38-44

KONDRASHOV, N.S., Kuybyshev

[Abstract] Steady-state harmonic oscillations and deformation waves are present around the periphery of a closed shell having constant parameters along this contour. Previous analyses of such systems have employed numerical integration to solve equations derived from a differential scheme describing the dynamic stiffnesses of composite cylindrical shells. This paper finds an analytical solution of the equations of motion, circumventing difficulties related to the transition through internal stress or motion nodes. The solution is illustrated with two sample calculations: 1) the determination of the resonant frequencies of a free shell made of 12Kh18N10T steel with flanges; the frequency between about 190 and 650 Hz is plotted as a function of the number of deformation waves, indicating good agreement between experiment and theory; 2) the forced oscillations of an orthotropic shell subjected to concentrated harmonic loads are determined. The shell is tightly closed at the ends and there is a stiffening rib in the center section to which the external forces are applied. The shell has a wall thickness of  $2 \cdot 10^{-3}$  m, radius of 0.2 m and a length of 0.44 m; the rib cross-section is  $0.17 \cdot 10^{-4}$  m<sup>2</sup>; the axial moments of inertia (width less than the height) are  $0.42 \cdot 10^{-8}$  m<sup>4</sup> and

$0.15 \cdot 10^{-8} \text{ m}^4$ ; the polar moment of inertia is  $0.5 \cdot 10^{-8} \text{ m}^4$ . The shell material has a density of  $1.84 \cdot 10^3 \text{ kg/m}^3$  with moduli of elasticity of  $0.9 \cdot 10^{10}$  and  $2.8 \cdot 10^{10} \text{ Pa}$ . Graphs are plotted for a ribless shell showing the bending and internal axial stresses for a concentrated axial force, a radial force and a concentrated axial bending moment at a frequency of  $1,500 \text{ sec}^{-1}$ . The behavior of the system with the stiffening rib is also shown graphically. Figures 5, references 5 Russian.  
[111-8225]

UDC 539.3:534.1

# CALCULATING THE OSCILLATIONS OF A SHALLOW SHELL WITH A RIGID INCLUSION

Kiev PRIKLADNAYA MEKhanika in Russian No 9, Sep 83 (manuscript received 17 Aug 81) pp 45-49

ANTUF'YEV, B.A., Moscow Aviation Institute

[Abstract] A thin elastic gently sloping panel of a shell contains an absolutely rigid but small lap plate (inclusion). This inclusion is located in the center of the panel so that its center of gravity falls in the central surface of the shell; the major central axes coincide with the orthogonal system of coordinates used in the analysis and the inclusion has geometric and stiffness symmetry relative to the coordinate lines. The equations of motion of the insert when subjected to dynamic interactions as well as external harmonic forces and moments are solved by representing the unknown reactions of the shell and insert in the form of a series of using Bubnov's method to reduce these equations to a system of linear algebraic equations in terms of the coefficients of expansion for the reaction and quantities describing the displacement of the insert. Successive approximations are used to determine the resonant frequencies of the system when the natural oscillations are unknown. This approximation technique is applied to the sample calculation of the lowest natural vibrational bending frequency of square panels having spherical and cylindrical shapes. The squares of the dimensionless lowest natural oscillation frequencies are plotted for these two shapes as a function of the ratio of the masses of the inclusion and shell. The contraction of the inclusion mass into a single material point has a considerable impact on the lowest natural frequency of spherical shell oscillation and little influence on the frequency of a cylindrical shell. When the above ratio increases, the successive approximations exhibit better convergence. In order to find the frequency with an accuracy of 1% when the ratio of the insert and shell masses is 0.2, 1 and 2, the number of iterations was 17, 4 and 3 respectively. The convergence is somewhat poorer for the cylindrical shell. Figures 2, references 7 Russian.  
[111-8225]

## STABILITY OF NONLINEAR OSCILLATIONS OF A TWO-BODY SYSTEM IN A CENTRAL FORCE FIELD

Kiev PRIKLADNAYA MEKhanika in Russian No 9, Sep 83 (manuscript received 8 Feb 82) pp 96-101

GULYAYEV, V.I., LIZUNOV, P.P. and PRUDENKO, N.N., Kiev Structural Engineering Institute

[Abstract] A system of two bodies experiences spatial oscillations relative to the center of mass of the system, which moves along an elliptical trajectory in a central Newtonian force field. The mass of the carried body is less than the mass of the carrying body, but not so much that the influence of the former on the oscillations of the latter can be disregarded. The carried body has three degrees of freedom and is tied to elastic support elements. The radius of inertia of the carrying body is much greater than the radius of inertia of the carried body, which makes it possible to neglect rotational motion of the carried body, assuming it to be a material point. Nonlinear differential equations of motion are written for the system and periodic solutions are found using a technique developed earlier by the author. The proposed approach is applied to three cases of nonlinear oscillations of such a system, which are distinguished by the initial position of the material point relative to the carrying body: 1) the material point is located at the center of inertia; 2) the material point is located in a plane referenced to the carrying body; 3) this point is located outside the plane of motion of the system center of inertia. It is shown that the location of the material point has a substantial impact on the nature of the relative motion of the system, and can produce both stabilization and destabilization. Figures 3, references 6

Russian.  
[111-8225]

## STUDY OF THE INFLUENCE OF ANNULAR STIFFENING RIBS ON THE NATURAL OSCILLATION FREQUENCIES OF CONICAL SHELLS

Kiev PRIKLADNAYA MEKhanika in Russian No 9, Sep 83 (manuscript received 7 Jul 82) pp 121-124

SKOSARENKO, Yu.V.

[Abstract] A closed truncated hinge-supported conical shell is stiffened with a regular network of ribs. The equations of motion for the shell, considering the discrete placement of the stiffening stringers, are written in accordance with the Ostrogradskiy-Hamiltonian principle in terms of differential operators and solved using the Bubnov-Galerkin technique. It is assumed that the shell is stiffened with a large number of longitudinal ribs, which allows a one-term approximation for the peripheral direction. The proposed

approach is realized using a unified system computer in Fortran-4 and applied to the problem of determining the mode and frequency of the natural oscillations of such a conical shell stiffened with stringers whose stiffness and number were varied. A simple analytical equation is also derived for the resonant frequency of a shell with two ribs. Graphs are plotted showing the frequency as a function of the total relative moment of inertia of the cross-section of the ribs for 2 to 14 ribs. For shells stiffened in this way, curves for the lowest frequencies as a function of the number of waves in the peripheral direction have a local minimum in addition to the global minimum. This is because the modes when the ribs are predominately bent correspond to the lowest resonant frequencies for a small number of ribs and in the case of a large number of ribs, the modes are related predominately to the twisting of the ribs. There is a minimum within the range of wave numbers corresponding to each of these two kinds of shell deformation. To increase the minimum frequency in the case of few ribs, the bending stiffness of the annular ribs must be increased. Figures 2, references 8: 6 Russian, 2 Western. [111-8225]

UDC: 531.8

#### OPTIMAL EQUATION OF A PENDULUM MODELING THE MOVEMENT OF A LEG BEING SHIFTED

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA in Russian Ser 19, No 4, Oct 83 (manuscript received 14 Mar 83) pp 63-68

KUDAYEV, S. P.

[Abstract] The leg of a bipedal walking machine which is being shifted (not carrying weight) is modeled by a homogeneous rod of known length in planar motion. The problem is to determine a control to transfer the shifted leg from its initial position to the position where it takes up weight while minimizing the expenditure of energy. An equation is derived which is the only limitation on parameters of the system required to assure the optimal control. Figure 1, references 6: 5 Russian, 1 Western. [95-6508]

UDC 539.3

#### STRESSED STATE OF THICK-WALLED SHELLS OF NONCANONICAL NEARLY SPHERICAL SHAPES

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 8, Aug 83 (manuscript received 14 Jun 82) pp 29-34

NEMISH, Yu.N., Institute of Mechanics, UkSSR Academy of Sciences, Kiev, and LYALYUK, D.F., Ivano-Frankovsk Institute of Petroleum and Gas

[Abstract] Under consideration are thick-walled closed shells of revolution whose outside and inside surfaces  $S_0, S_1$  are described by the equations

$$\begin{aligned} R &= \rho \sin \gamma - \varepsilon \rho^{-3} \sin 3\gamma \\ z &= \rho \cos \gamma + \varepsilon \rho^{-3} \cos 3\gamma \end{aligned}$$

in a curvilinear orthogonal system of coordinates  $\rho, \gamma, \varphi$  ( $R$  - distance from axis of rotation  $z$ , parameter  $\varepsilon = \text{const}$  and  $|\varepsilon| \ll 1$  characterizing the departure of surfaces  $S_0 \sim \rho = 1$  and  $S_1 \sim \rho = \rho_0 > 1$  from the corresponding spherical ones  $\varepsilon = 0$ ). Such shells are biconical barrels when  $\varepsilon > 0$  and cylindrical barrels when  $\varepsilon < 0$ . Stresses  $\sigma_{\gamma\gamma}, \sigma_{\varphi\varphi}$  and their distributions in such shells under uniform static external or internal pressure are calculated by solving the equations of balance analytically according to the method of boundary shape perturbations with series expansion in Legendre polynomials and their first and second derivatives, with the boundary conditions for this axisymmetric problem stipulated in one form applicable to any approximation, and with the shell material assumed to be homogeneous and isotropic. Numerical solutions have been obtained for a bi-conical shell with  $\varepsilon = 0.05$  and a cylindrical shell with  $\varepsilon = -0.05$  under internal pressure, with the inside radius  $\rho_i = 1$  and the outside radius  $1.2 \leq \rho_0 \leq 3.0$ , assuming a material with the Poisson ratio  $\nu = 1/4$ . Calculations were made on a BESM-4M high-speed computer. Figures 6, table 1, references 8 Russian. [150-2415]

UDC 539.3

#### STRESSED-STRAINED STATE OF TUBULAR SHELLS UNDER UNIFORMLY DISTRIBUTED PRESSURE

Kiev PRIKLADNAYA MEKhanika in Russian Vol 19, No 8, Aug 83 (manuscript received 29 Jun 82) pp 11-18

GRIGORENKO, Ya.M., GULYAYEV, V.I., GOTSULYAK, Ye.A. and ASHURI, K., Institute of Mechanics, UkSSR Academy of Sciences, Kiev; Kiev Institute of Structural Engineering

[Abstract] Stresses and strains in cyclic shells generated by a cricle moving parallel and in channel shells with a curving planar centerline are analyzed according to the linear theory of elasticity and the moment theory of shells. The corresponding force and moment balance equations are solved by the method of finite differences for various boundary constraints determining the state of stress and strain, with the components of membrane forces and moments expressed through elongation tensor and deflection tensor components. Tangential strains are approximated by averaging them arithmetically over the internal of numerical differentiation, which ensures fast convergence of the solution. Numerical results are shown for shells under uniform internal pressure with three different combinations of deflection function, membrane force function, and membrane moment function. Three different generating circles are considered for each combination: one with constant radius, one with linearly varying radius, and one with cosinusoidally varying radius. Figures 5, table 1, references 8 Russian. [150-2415]



## RESEARCH IN THE FIELD OF RIB STIFFENED SHELL STABILITY

Kiev PRIKLADNAYA MEKHANIKA in Russian No 11, Nov 83 (manuscript received 21 Jan 83) pp 3-20

AMIRO, I.Ya. and ZARUTSKIY, V.A., Institute of Mechanics of the UkrSSR Academy of Sciences, Kiev

[Abstract] Since the extensive use of rib stiffened shells as structural members was reviewed in a detailed survey published in 1968, this paper surveys only that literature appearing after 1967, devoting primary attention to theoretical and experimental studies of the influence of a regular pattern of the ribs on the shells. The following are reviewed: fundamentals of stiffened shell theory, design procedures, analysis of computed data, aspects of optimization of structural designs, procedures and results of experimental studies as well as comparisons of experimental and theoretical data. General conclusions are: 1) with an increase in the number and stiffness of reinforcing ribs, the difference between experimental and theoretical data on critical loads is reduced, which is most likely because the stiffening of shells with ribs reduces the influence of the initial bends; 2) even with a rather large number of ribs, losses of shell stability are accompanied by wave formation, which is evidence of the influence of the discrete patterned placement of such ribs; 3) it is possible to have a considerable difference between the stability losses of a shell determined experimentally by means of critical loading and the load at which it actually loses its carrying capacity. The most urgent problems at present are those related to shell stability for various types of combined loads, especially nonuniform loading, including exposure to concentrated forces. Studies are also needed on the reasons for the difference between the experimental and theoretical critical load values. References 189: 155 Russian, 44 Western.  
[113-8225]

## UNSTEADY STRESSED STATE OF TWO-LAYER CYLINDER WITH CONTACT THERMAL RESISTANCE

Kiev PRIKLADNAYA MEKHANIKA in Russian No 11, Nov 83 (manuscript received 6 Jul 82) pp 46-51

MOTOVILOVETS, I.A., KOMAROV, G.N. and CHERVINKO, O.P., Institute of Mechanics of the UkrSSR Academy of Sciences, Kiev and Kiev Trade and Economics Institute

[Abstract] The conditions for ideal thermal contact between individual layers of multilayered structures are rarely met. This paper considers this fact in the study of the planar nonsteady-state temperature field and stressed state of a two-layer cylinder, assuming that there is ideal mechanical contact between the layers and the coefficient of thermal resistance between the layers is a constant. Second order partial differential equations are solved to find

the temperature field and stresses. A sample numerical solution for a two-layer cylinder shows that the interlayer thermal resistance has a substantial impact on temperature and stress distribution within the cylinder. Figure 1, references 3 Russian.  
[113-8225]

UDC 539.3

# STRESSED STATE OF MULTILAYER THICK-WALLED LONGITUDINALLY CORRUGATED CYLINDERS

Kiev PRIKLADNAYA MEKHANIKA in Russian No 11, Nov 83 (manuscript received 30 Dec 82) pp 52-58

NEMISH, Yu.N. and MATYASH, Yu.I., Institute of Mechanics of the UkrSSR Academy of Sciences, Kiev

[Abstract] A multilayer hollow cylinders has longitudinal corrugations in the outer surface and the separation surfaces between the layers. This cylinder is subjected to axially symmetric forces on these surfaces; the forces are such that the desired stresses and strains are analytic functions of the radius. This paper provides a general solution of the three-dimensional boundary value problem for such composite cylinders with wavy surfaces. The technique is illustrated with the example of a two-layer cylinder having different corrugation geometries: 1) only the separation surface between the inner and outer layers is corrugated, with 8 wave crests and troughs around the periphery as viewed in cross-section; 2) only the exterior surface of the cylinder is corrugated, again with 8 corrugations; 3) the outer surface and separation surface are both corrugated with 8 corrugations, where the peaks and depressions of the corrugations coincide as viewed in cross-section; 4) the outer and separation surfaces each have 8 corrugations with the troughs of the outer corrugations coinciding with the peaks of the inner corrugations. The proposed approximation technique is used to determine the stresses in such cylindrical configurations subjected to a variable axially directed internal pressure. The influence of the mechanical properties of the layers on the stress-strain state of the cylinders is illustrated graphically. Tables 3, figures 5, references 9: 7 Russian, 2 Western.  
[113-8225]

## TESTING AND MATERIALS

UDC 621.039.531

### SURFACE DAMAGE TO STRUCTURAL MATERIALS BY PLASMOIDS

Moscow ATOMNAYA ENERGIYA in Russian Vol 56, No 2, Feb 84 (manuscript received 13 Jun 83) pp 83-88

POL'SKIY, V.I., KALIN, B.A., KARTSEV, P.I., SKOROV, D.M., FOMINA, Ye.P., SKVORTSOV, Yu.V., UMRIKHIN, N.M., KHAMIDULLIN, F.R., TSEREVITINOV, S.S., KOZHEVNIKOV, O.A., LAPIN, A.N. and ODINTSOV, N.B.

[Abstract] The action of plasmoids on structural materials in nuclear fusion plants, leading to surface erosion and breakdown of the first wall, was studied in an experiment with an MK-200 pulse-type accelerator generating hydrogen or deuterium plasmas. The accelerator operated with cylindrical or conical electrodes, a cylindrical tube-liner made of stainless steel (length 1.5 m, diameter 0.3 m, wall thickness 2 mm) feeding the plasmoids to the test stand. In the first series of tests each specimen was subjected to three impacts by 30 kJ hydrogen plasmoids coming from the accelerator with cylindrical electrodes (accelerating voltage 15 kV, discharge energy 125 kJ). In the second series of tests each specimen was subjected to thirteen impacts by 70 kJ deuterium plasmoids coming from the accelerator with conical electrodes (accelerating voltage 30 kV, discharge energy 500 kJ). The basic plasma parameters in this study corresponded to International Tokamak Reactor Workshop recommendations. The materials tested were refractive molybdenum alloys (Mo-Zr, Mo-Al, Mo-V), stainless steels (12Kh18N10T, 03Kh20N45M4B4, 03Kh20N45M4B4-RTs, 07Kh16N4B, cast and sintered OKh16N15M3B and Kh13M2), aluminum (A-999), titanium (VTI-00), titanium alloy (PT-7M Ti-Al-Zn), coated stainless steel (12Kh18N10T calorized with aluminum), coated niobium (spray-coated with aluminum), and coating materials (graphite G-4, glass-graphite SG-2,  $Al_2O_3+V_2O_3$ , SiC, carbon-pyroceramics US-1, USB-15). Surface defects and erosion were examined by microstructural and topographical analysis, including diffractometry with radiation from an Fe anode. The results reveal that graphite and glass-graphite are most plasma-resistant, while spray-coated niobium and calorized stainless steel are most vulnerable. All coating materials remained nondefective after the first three plasma impacts and cracked only during the subsequent series of thirteen plasma impacts. All other materials revealed cracks along grain boundaries, blisters, grain cracks, craters, drops and curls of solidified metal, or local beads beginning during the first test series. Figures 7, tables 2, references 21: 14 Russian, 7 Western.

[146-2415]

## PRELIMINARY RESULTS OF TESTING STRUCTURAL AND HEAT ACCUMULATING MATERIALS FOR COMPATIBILITY

Tashkent GELIOTEKHNIKA in Russian No 5, Mar 83 (manuscript received 7 Apr 82) pp 38-42

TRUSHEVSKIY, S. N., SIDOROV, P. P., TROKHININ, N. N., SHALIMOVA, L.N. and SHMAKOVA, S. N., All-Union Order of Labor Red Banner Scientific Research Institute of Electric Power Sources

[Abstract] A study is made of two temperature intervals: 40-75°C and 250-300°C. Thermal accumulators in the 40-75°C interval were crystal hydrates, structural materials for this interval type St3 steel, D-16T aluminum alloy and L-62 brass. It is concluded that  $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  is compatible with D16T anodized,  $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  is compatible with D16T anodized, St3, L-62 and various paints and varnishes, epoxy resin EP00-20 and EP-773 enamel,  $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$  is compatible with St3 steel and  $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$  is compatible with L-62 and St3. In the higher temperature interval salt-alkali eutectics  $\text{NaCl-ZnCl}_2$ ,  $\text{LiCl}_2\text{-LiOH}$ ,  $\text{LiCl-LiNO}_3$  and  $\text{KBr-KOH}$  were studied for compatibility with stainless steel, NVK nickel and type 45 steel. The results showed that steels Kh18N10T, 08Kh18N10 and 45 can be considered promising structural materials for heat accumulators operating in this range. Nickel can be used with the  $\text{NaCl-ZnCl}_2$  and  $\text{LiCl-LiNO}_3$  eutectics. References 4 Russian. [100-6508]

UDC: 536.21

## HEAT CONDUCTIVITY OF KO-2 OPTICAL CERAMIC

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84 (manuscript received 27 Sep 82) pp 30-31

LUGUYEVA, N. V., DRONOVA, G. N. and LUGUYEV, S. M.

[Abstract] Results are presented from a study of heat conductivity of KO-2 optical ceramic in the 80-400 K temperature interval. Heat conductivity was measured by an absolute stationary method in specimens prepared by recrystallization pressing in a vacuum in installations with radiant heating of the glass mold and with low frequency induction heating. The initial raw material used was finely dispersed zinc sulfide powder. Specimens had relative density 0.998, grain size 1-2  $\mu\text{m}$ . X-ray structural analysis showed that they had cubic structure. The experimental studies showed that due to the specifics of the structure of KO-2 optical ceramic its heat conductivity coefficient is less than that of a ZnS single crystal. Figures 2, references 8: 4 Russian, 4 Western. [89-6508]

## ANGLE MEASURING INSTRUMENT WITH QUASI-IDEAL COORDINATE SYSTEM

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 10, Oct 84  
(manuscript received 30 Dec 82) pp 45-48

MEYTIN, V. A. and CHERNOV, V. S.

[Abstract] It seems promising to create an angle measuring instrument in which the geometry of the axes, their deformation and deformation of the tube would not influence accuracy. This can be done if the axes are connected to mirror-prism carriers of the coordinate system generating ideal, abstract coordinate systems. This article describes an angle measuring instrument with quasi-ideal coordinate system, including a diagram of the device and mathematical analysis of its characteristic. It is determined that if at fixed moments in time we know the values of all deflections and rotations, the exact position of the sighting axis can be determined for those moments in time. The angle measuring instrument with quasi-ideal coordinate system may be compact or quite large, up to several meters, operating in static or dynamic mode with photoelectric reading devices and a computer for computation of coordinates. The system of angle measurement here described can be used to create universal astronomical instruments, theodolites, radio telescopes and satellite geodesy devices. Figures 3, references 6 Russian. [89-6508]

UDC 621.833

## TOOTH WEAR IN WORM GEARS IN VACUUM

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 12, Dec 83 (manuscript received 26 Apr 83) pp 42-47

DEULIN, Ye.A., candidate of technical sciences, and VAGIN, N.S., graduate student

[Abstract] The tooth wear in worm gears in vacuum is analyzed, assuming a flexible pinion with involute tooth profile and a meshing zone symmetric with respect to the major pinion deformation axis. Experimental studies have established that this wear is adhesive and excessive in the case of dry friction and abrasive in the case of mechanically deposited solid lubricant with attendant boundary friction. This controllable abrasive wear, of both tooth base and coating materials, is calculated on the basis of linear dependence on the contact pressure. For this purpose the force and displacement profiles during engagement of meshing teeth are determined. The resulting formula for total wear reveals that the latter is proportional to the number of meshing teeth within the range of the major pinion deformation axis. On the basis of experimental data covering a wide range of alloy steels, values of the wear coefficient are recommended for use in engineering design calculations of tooth life, backlash, and necessary coating thickness according to this formula. Figures 3, references 4 Russian. [149-2415]

UDC: 551.46.006:551.4.08:681.883,004.14

DETERMINATION OF HYDROPHONE SENSITIVITY AS A FUNCTION OF HYDROSTATIC PRESSURE

Moscow IZMERITEL'NAYA TEKHNIKA in Russian No 11, Nov 83 pp 50-51

DMITREVSKIY, N. N. and ZOTOV, A. I.

[Abstract] Two converters are studied, one excited by current and acting as a radiator, another acting as the receiver. A method is developed for estimating the changes in sensitivity of piezoceramic hydrophones as a function of hydrostatic pressure under laboratory conditions for these two devices at pressures of up to 50-60 MPa. The results indicate that the error in estimation of sensitivity using the method suggested is not over 1 dB, quite acceptable for practical applications. Figures 2, references 4: 3 Russian, 1 Western. [106-6508]

UDC: 534.8:629.12

ACOUSTICAL MEASUREMENTS IN SHIPBUILDING

Moscow IZMERITEL'NAYA TEKHNIKA in Russian No 11, Nov 83 pp 48-50

KOLESNIKOV, A. Ye.

[Abstract] The specifics of acoustic processes experimentally studied in shipbuilding include great variety, complex conditions of occurrence and strong variation with time and space factors. The major methods of acoustical measurement developed in the 1930's and 40's are not in successful use in shipbuilding. Their automation has been facilitated by the development of electronic computers. Parametric sound radiators and detectors are combined with interferometric methods of measurement to provide precise estimation of the nature of acoustic phenomena in structures under construction. Soviet developments relating to acoustical measurements in shipbuilding are at the highest current level of achievement of acoustics, electronics and computer technology. Figure 1, references 15: 13 Russian, 2 Western. [106-6508]

UDC: 389.14:531.74.089.68:62-229

STUDY OF STABILITY OF OPERATING ANGLES OF MULTIFACETED METAL PRISMS

Moscow METROLOGIYA in Russian No 12, Dec 83 pp 25-30

KOPYTOV, V. V.

[Abstract] Prisms made of type ShKh-15, KhG and KhVG steel with 15, 18, 20 and more faces have been manufactured in an attempt to improve the

manufacturing technology of the prisms, which are used as standards for calibration of optical divider heads, goniometers and other high-precision measurement devices. High tempering cannot be used in these devices to stabilize the austenite-martensite conversions which might increase dimensional stability, since it reduces the hardness of the steel. Several researchers have recommended repeated cold treatment and low-temperature tempering to ensure complete decomposition of residual austenite. The authors tested triple "artificial" aging by holding for 12 hours at 100°C, then 12 hours at -60°C. Maximum deviations from flatness of the faces of metal prisms thus treated were found to be not over 0.04  $\mu\text{m}$ . Figure 1, references 10 Russian. [90-6508]

UDC: 681.586.5-187.4:531.71

#### INCREASING ACCURACY OF PRECISION LINEAR AND ANGULAR MOVEMENT TRANSDUCERS

Moscow METROLOGIYA in Russian No 12, Dec 83 pp 18-19

SADOV, V. S., SHESTAKOV, K. M., PAVLOV, L. I., ROMANOV, A. V. and VASILEVSKIY, V. Ye.

[Abstract] A method is analyzed for processing signals for commonly used high precision photoelectric and interferometric linear and angular movement transducers with sine and cosine output signals, the phases of which are proportional to the movement of the objects. The method studied can decrease the requirement for accuracy of design and adjustment of the sensors. It can also be used to regulate the phase shift between harmonic signals and to convert a phase shift to an amplitude. Figures 2, references 3 Russian. [90-6508]

UDC: 681.327.12.065:369.21(088.8)

#### MEASUREMENT OF ANGULAR QUANTITIES IN GRAPHIC INPUT DEVICES

Moscow METROLOGIYA in Russian No 12, Dec 83 pp 12-17

TORM'SHEV, Yu. I.

[Abstract] Methods are studied for measuring angular quantities allowing the processes of measurement and coding of information to be performed simultaneously. The basis of the process of measurement of angles in graphic input devices is the possibility of successive determination of the coordinates of the input device moved over the surface of the graphic device. Due to the discrete nature of the process of measurement of coordinates, the computed trajectories of movement of the moving device form a step function similar to the trajectory obtained by interpolation of a circle. Errors inherent in the method are analyzed. It is demonstrated that as the measurement device is moved it is possible to determine a quantity directly proportional to the

angle of its rotation and, consequently, to the angle between two measured sectors. The method allows measurement of angles between sectors, the intersection of which is outside the area of the input device. Figure 1, references 1 Russian.  
[90-6508]

UDC: 621.315.616.019.34.001.3

#### RELIABILITY OF INSULATION OF SUBMERSIBLE ELECTRIC MOTORS

Moscow ELEKTRICHESTVO in Russian No 11, Nov 83 (manuscript received 30 Mar 82) pp 64-66

MESENZHNİK, Ya. Z., candidate of physical and mathematical sciences,  
PRUT, L. Ya. and KARTASHOV, B. G., engineers

[Abstract] Polymer insulation of the following types was studied: I - polymer enamel, Mylar film and wound Mylar fiber; II - double-layer insulation of high- and low-pressure polyethylene; III - multi-layer insulation of non-oriented Teflon film covered with oriented Teflon film; IV - polyamide enamel and kapton-F insulation; V - fluoroplast-40Sh insulation. The behavior of these materials was studied experimentally as a function of variation in pressure  $P$  and temperature  $T$ . The variations in  $\rho_{equiv}$  as  $P$  increases becomes smaller as the equivalent density of the insulating construction increases. Both electrical and thermal breakdown of the insulation can occur. The theory of the electrical conductivity of organic molecular crystals is used to describe the electron electrical conductivity polymer; the mechanism of diffusion in polymers is used to describe ion conductivity. References 14 Russian.  
[131-6900]

CSO: 1861

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